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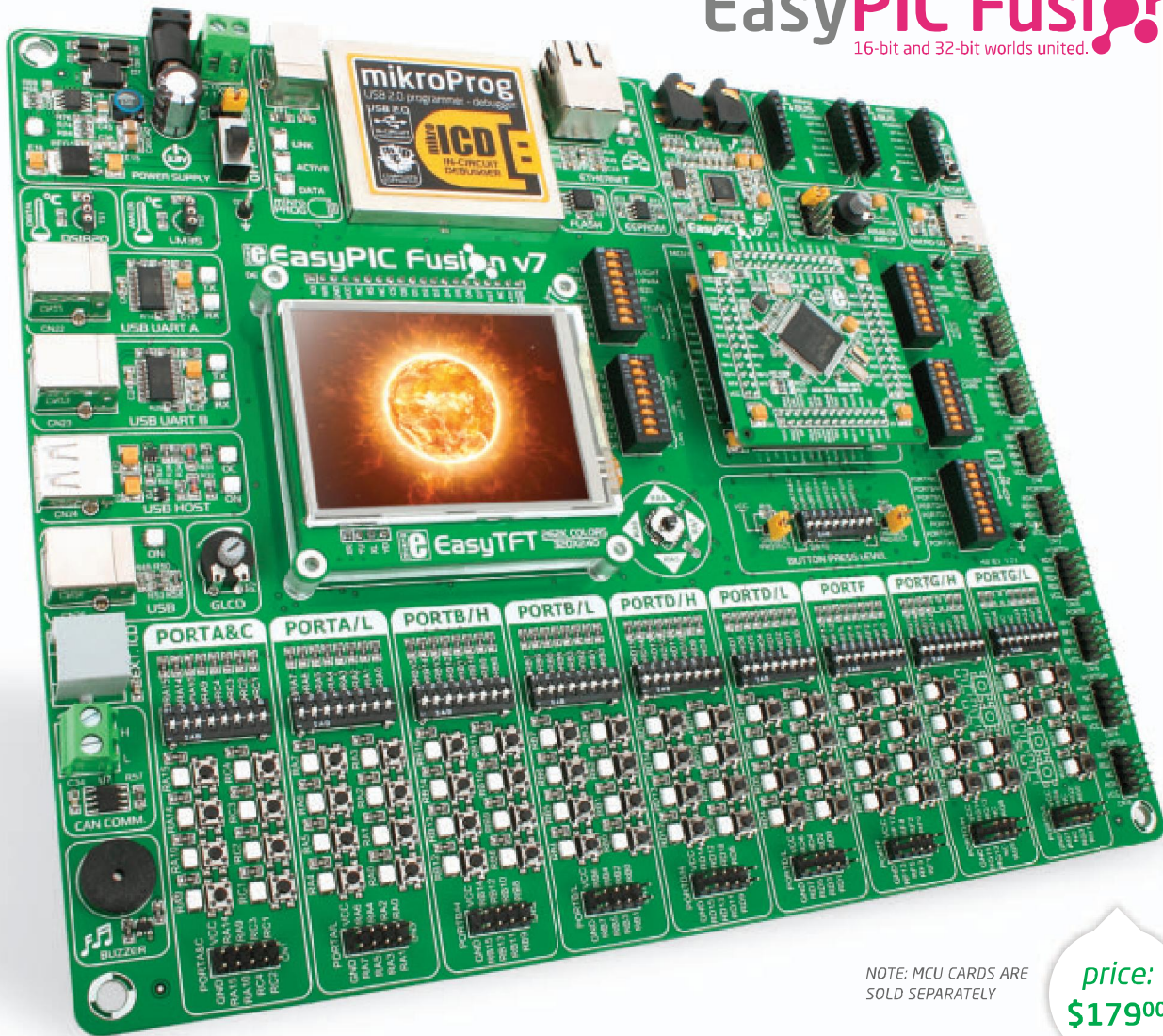
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# May 2013



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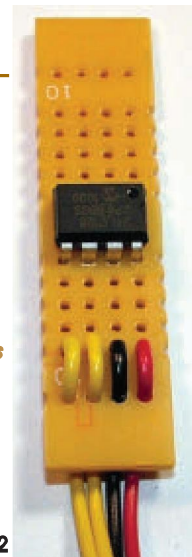
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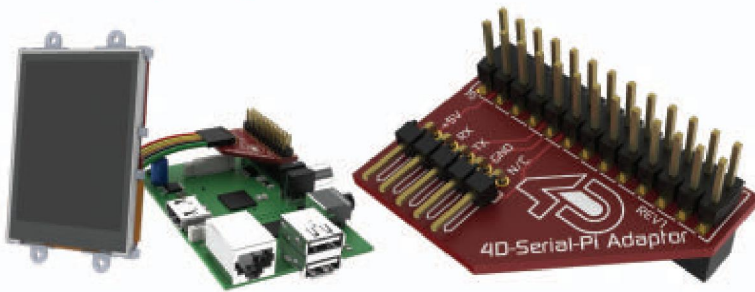
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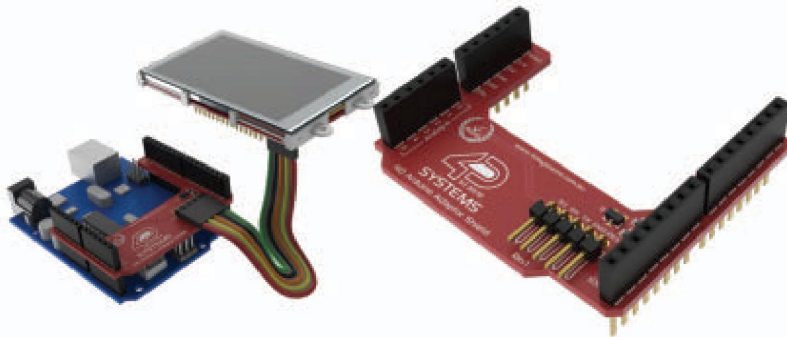
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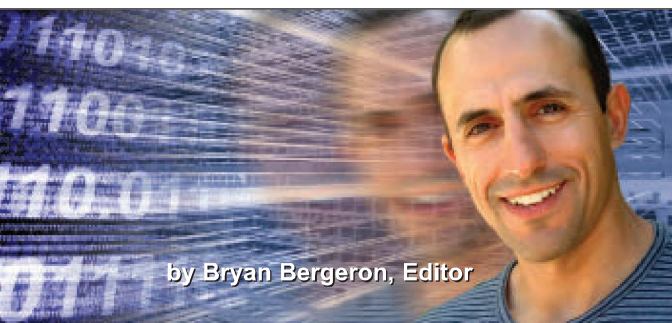
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## Vulnerabilities of Networked, Embedded Systems

In case you haven't noticed, just about everything can be networked with embedded hardware. Take automobiles. Besides the obvious wireless connectivity for your cell phone and GPS, the brakes, headlights, wipers, radio, and transmission are all monitored, controlled, and connected by microcontrollers. At home, there's a wireless monitor for humidity in my music room, with an alarm set to sound if humidity drops below 45%. There's also a wireless network of smoke and CO detectors that sound at the first hint of a fire.

I've assumed for years the major cost of ubiquitous embedded system networks is low-level radiation from Wi-Fi hot spots and Bluetooth devices. That's not the only cost, however. The problem with networked embedded

systems — as they grow more powerful and more plentiful — is the potential for harm.

It's one thing for a government to remotely destroy the equipment purportedly used to make nuclear weapons, and quite another for someone to change the setting on your IV drip while you're in the hospital. Or, to cause your car's anti-skid brake system to lock up as you accelerate to pass. Or, by someone who remotely shuts off the oxygen to your aircraft cabin. What if someone parked in a car outside your home or office could shut down your pacemaker?

The problem with malicious embedded system crashes is that they can result in physical crashes, as opposed to the soft crashes on a computer screen. Recognizing this, DARPA and other government agencies are funding research to develop means of automatically detecting and patching vulnerabilities in networked, embedded systems.

This is no small task. Think about the difficulty in handling malware on desktop computers. You have to first identify the malware with a program such as McAfee or Symantec. Then, you have to get rid of the malware and patch the corrupted software.

As you may have experienced first-hand, it's rarely straightforward. I can recall having to format my hard drive and reinstall software at least once in the past few years because of malware I couldn't remove by other means.

So, what are the practical implications of this reality? I suggest you consider the worst-case scenario. Let's say everyone in your family has a tablet computer with GPS and video cameras. What could someone do with the location information and perhaps a few real time snapshots? Certainly, these would be an advantage to a would-be burglar.

What about that quadcopter you've been building, complete with waypoint software? What if, on your next flight, someone usurps your uplink, and they fly the quad into a moving car? Or, simply force it to land and take your investment with them?

For now, the operative term is vigilance. To my knowledge, there isn't a standard 'security' library for the Arduino, Propeller chip, or other popular microcontroller capable of automatically identifying and eradicating malware. Of course, as with malware for the big iron, as soon as protection becomes standardized, the malware makers will adapt.

Perhaps it's a good time to buy stock in a malware protection company. **NV**

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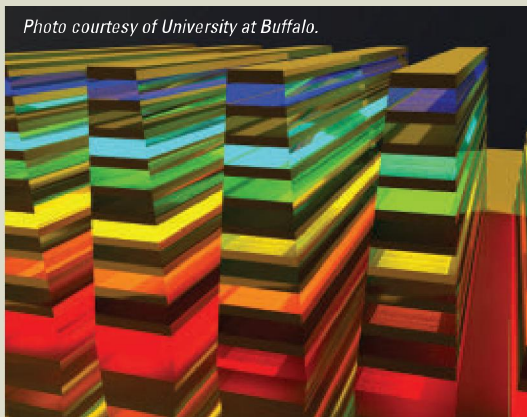
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## ADVANCED TECHNOLOGY

Photo courtesy of University at Buffalo.



■ A new type of waveguide catches and absorbs colors vertically.

### RAINBOW ON A CHIP

If you have always wanted to raise unicorns or have tea with a wood nymph, well, you're still out of luck. If your desire is to catch a rainbow, however, take heart. Asst. Prof Qiaoqiang Gan and some PhD

students from the University at Buffalo ([www.buffalo.edu](http://www.buffalo.edu)) recently published a paper describing how to do it. It all started with Gan's interest in slowing down the flow of photons which traditionally has been done using cryogenic gases. At near absolute zero, light can be made to travel at roughly the speed of a mo-ped.

While at Lehigh University, Gan helped develop an alternative method that involved creating various depths of nanoscale grooves in metallic surfaces, thereby altering the material's optical properties to achieve the same effect. Further research at Buffalo led to the new development, described as "an advanced microchip made of alternate ultra-thin films of metal and semiconductors and/or insulators. The waveguide halts and ultimately absorbs each frequency of light at slightly different places in a vertical direction to catch a 'rainbow' of wavelengths."

"Electromagnetic absorbers have been studied for many years, especially for military radar systems," according to Gan. "Right now, researchers are developing compact light absorbers based on optically thick semiconductors or carbon nanotubes. However, it is still challenging to realize the perfect absorber in ultra-thin films with tunable absorption band. We are developing ultra-thin films that will slow the light and therefore allow much more efficient absorption which will address the long existing challenge."

The "hyperbolic metamaterial waveguide" is able to capture a range of wavelengths in different frequencies, including visible, near- and mid-infrared, teraHertz, and microwave. According to Gan, this could lead to practical applications in solar panels, stealth coatings, electronic crosstalk reduction, and other fields. Be careful how you use this stuff, though. An old Bulgarian legend has it that if you walk under a rainbow, you will undergo gender reversal. ▲

### FAREWELL TO BOTULISM

There are basically two types of people in the modern world: those who ignore food expiration dates and wolf down anything that doesn't look fuzzy, slimy, or otherwise decayed; and those who believe that a bag of pork rinds can be fresh and crunchy one day but toxic the next. According to a 2011 study by the United Nations, the latter type of person is responsible for tossing out millions of tons of food each year — much of which is perfectly safe and savory. At the 2013 International Solid-State Circuits Conference ([www.isscc.org](http://www.isscc.org)) held in San Francisco, researchers from STMicroelectronics ([www.st.com](http://www.st.com)) and three European universities revealed a first-of-its-kind plastic, printed analog-to-digital converter (ADC) that may enable fabrication of sensor circuits that cost less than one cent. Such circuits could replace expiration dates on food and pharmaceutical packages with real time information, thus saving both money and landfill space.

In operation, one would incorporate the ADC in a standard sensor circuit, with the sensor detecting things like acidity level changes in the food. By combining the sensor and ADC with an amplifier and a radio transmitter, one could determine the condition of the food via a simple scanner or even a mobile phone. Of the four components, the ADC has been the only missing link, so it is now possible to complete the package. The last step is to integrate them all into a smaller unit. Unfortunately, the researchers expect it to take at least five more years before the devices start to appear on supermarket shelves. I'm pretty sure everything that's in the kitchen now will be okay until then. ▲

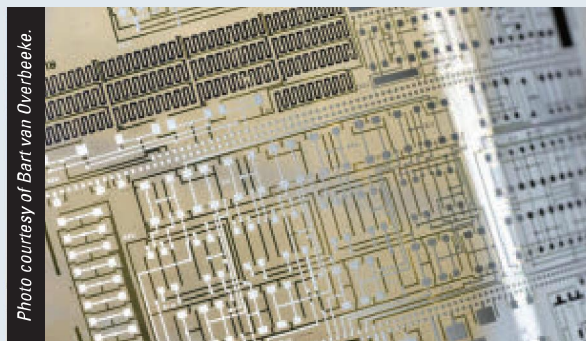


Photo courtesy of Bart van Overbeke.

■ Plastic analog-to-digital converter (ADC) to be miniaturized later.



Discuss this article in the Nuts & Volts forums at <http://forum.nutsvolts.com>.

## COMPUTERS AND NETWORKING

### DELL INTRODUCES ENHANCED SECURITY

The Latitude 10 from Dell ([www.dell.com](http://www.dell.com)) is a rugged tablet fitted with a magnesium alloy frame and a Gorilla Glass face, targeted for users within government agencies, financial institutions, and health care organizations. The company recently introduced the Enhanced Security configuration which includes a smart card and fingerprint reader. Plus, there is an optional extended-life battery that provides up to 20 hours of operation on a charge.

The machine is not an overpowering piece of hardware, with its dual-core Atom Z2760 processor and a maximum of 128 GB internal storage. With large institutions migrating into the cloud, that may be sufficient.

It features a 10.1 inch, 1366 x 768 screen which makes its resolution comparable to that of a standard iPad, and Dell emphasizes that the Windows 8 Pro



■ Dell's Latitude 10 tablet, designed for government agencies, financial institutions, and health care organizations.

machine is considerably quicker and cheaper to set up. Specifically, the company claims that third-party testing has shown that the Latitude is "up to 17 times faster and 94 percent less expensive to deploy," and "up to 85 percent cheaper per device to maintain over a three year period." You can pick up the Enhanced Security model for an MSRP starting at \$779. ▲

### GIMP IS GOOD

If you are in the business of producing professional-level graphics and print publications, you probably have to worry about things like color saturation, profiles, destination space, and so forth. This means that it's nearly impossible to avoid the abominable prices and customer-hostile support associated with the well known multimedia software company that we shall refer to simply as "Satan." However, if your needs aren't quite so demanding and you're looking for a high level image editing application that won't require you to cough up \$700 or more, take a look at the GNU Image

Manipulation Program (better known as GIMP).

It can be used as a paint program, a quality photo retouching app, an online batch processing system, a mass-production image renderer, an image format converter, and so on. Standard features include many of the same sort of filters, brushes, layers, and other tools that are found in the best graphics applications, and you can even get the GIMP Animation Package if you want to move beyond still images. GIMP has received an "excellent" rating by *PCMag* editors, and *PC World* has dubbed it "ready to take on Photoshop."

It is certainly more complicated than your average \$29.95 paint program, but online tutorials are available to get new users over the rough spots. The best part is that it is distributed under the GNU General Public License, so it sells for the absolutely marvelous price of zero. (The developers do, of course, welcome donations.)

GIMP is written and developed under X11 on UNIX platforms, but it also runs on MS Windows and Mac OS X. All you have to do is log onto [www.gimp.org](http://www.gimp.org) and hit the download button to strike a blow against Satan. ▲



■ Wilber, the official mascot of the GIMP graphics application.



# CIRCUITS AND DEVICES

## GET CUBIFIED

Let's face it. Ever since you began reading about 3D printers, you've wanted one. Unfortunately, most are geared to industrial design applications, are complicated, and can run you tens of thousands of dollars. However, 3D Systems ([www.3dsystems.com](http://www.3dsystems.com)) has released the second generation of its 3D printer lineup, beginning with the Cube — a desktop unit that connects wirelessly to your PC or Mac, takes up only 10 x 10 inches on your desktop, and has been dubbed "easiest to use" and "most reliable" by *Make Magazine*.

The Cube can use both recyclable ABS plastic and compostable PLA cartridges; the materials are available in 16 different colors, including glow-in-the dark green and blue and metallic silver. You also get three choices of fill density: light, medium, and solid. The main limitations are that your creations can't be larger than 5.5 inches cubed, and you shouldn't expect to crank things out at commercial production rates; printing out a case for your smartphone will take about two hours. Of course, 99 percent of the stuff you print out will be totally useless. But fun is fun.

The complete Print Pack can be had for \$1,399, including the Cube printer, four cartridges, and the Cubify Invent design software. After that, cartridges will run you \$49 each. According to the company, one cartridge will make 13 or 14 average items. If you need to print larger things (and have a fatter wallet), you can opt instead for the CubeX at \$2,499 and generate things as large as a basketball. Plus, the Duo (\$2,999) and Trio (\$3,999) versions can print in two and three colors (respectively). For info on other 3D printers, be sure to check out the new series by Michael Simpson, starting in the May 2013 issue of *SERVO Magazine*. ▲



■ The Cube brings 3D printing to your desktop.

## FLASHY MOBILE PHONES ARE COMING

You may not have thought about it, but even though your mobile phone may be snapping photos that are on par with those of a decent quality digital camera, there is something missing: the flash. At present, flash units are just too large and power hungry to be included.



■ Xenon's prototype flash unit, designed for mobile phones.

However, the folks at Singapore's Xenon Technologies ([www.xenon-technologies.com](http://www.xenon-technologies.com)) have latched onto a "revolutionary" capacitor developed at Nanyang Technological University ([www.ntu.edu.sg](http://www.ntu.edu.sg)) and come up with a compact flash unit that should change all that.

The cap is made from layered polymers, so it takes up only about 25 percent of the space required by electrolytics. It is several times faster than today's ceramic components, yet it delivers a charge that's powerful enough to drive the kind of high intensity xenon flashes found in digital cameras.

The unit has yet to migrate from research lab to production, but the NTU-Xenon team is expected to develop a working commercial prototype by September 2013. ▲



## CIRCUITS AND DEVICES CONTINUED

### THINK YOU HAVE A BIG SCREEN TV?

So, you went to Walmart and bought yourself the biggest LED TV you could get. So, of course, you think it's pretty impressive. But does it have a 201 inch high-res Retina display in a 16:9 aspect ratio? Does it display 4.4 trillion colors? Does it have a 100,000 Hz refresh rate (500 times that of a standard TV) and a 6 mm pixel pitch to provide a bright picture even in full daylight? Does it include six 250W broadband speakers for the left and right audio channels, plus three 700W subwoofers — all designed to withstand any weather condition?

Does the remote include a fingerprint sensor so no one can change the channel back to Dr. Phil when you're not looking? Does it fold itself into a monolith and retract into its own hermetically sealed, below-ground storage



■ The C Seed 201 outdoor entertainment system is definitely not for everyone.

unit until needed again? Was it created by Porsche Design Studio ([www.porsche-design.com](http://www.porsche-design.com)) and built by C Seed Entertainment Systems ([www.cseed.tv](http://www.cseed.tv))? Did it cost €500,000 (\$655,000)? I didn't think so. ▲

## INDUSTRY AND THE PROFESSION

### IEEE MEMBER'S PREDICTIONS

Back in January, the IEEE ([www.ieee.org](http://www.ieee.org)) ran 2013 Gadget Graveyard — a Facebook application in which more than 1,700 members, engineers, engineering students, and CES attendees opined about which devices will or will not disappear in the coming year. "The Gadget Graveyard results have telling implications about the rapid pace of advancement in technology," noted Stefan Mozar, president of the IEEE Consumer Electronics Society. "In the technology industry, we tend to think about 'what's next.' But it's also important to revisit the value of heritage devices and remember that despite constant innovation, it can take time for new technology to gain widespread adaptation."

Number one on the deathwatch list was CD-ROMs, with 75 percent voting for their imminent demise. Next in line were radios (58 percent), MP3 players (55 percent), DVDs (53 percent), and cable boxes (51 percent). Respondent's votes indicated that many mundane technologies will live on for at least another year, including desktop computers (62 percent). They shunned multifunction devices and endorsed the continued existence of stand-alone cameras (75 percent), car

keys (60 percent), and GPS systems (58 percent). They also voted in favor of printers (81 percent) and paper money (74 percent), so the world may not be changing as rapidly as some would have it. **NV**



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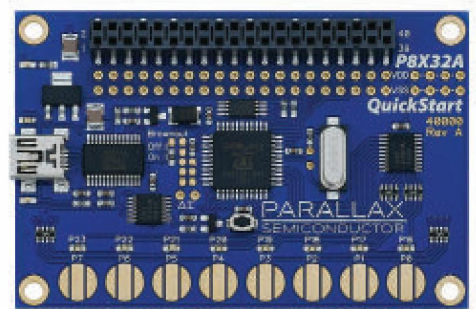
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## A QUICKSTART TO PROPELLER FUN

**When I first became interested in embedded microcontrollers — back in the early 90s — about the only choice for a hobbyist like me was the roll-your-own route, until Parallax came along and introduced the BASIC Stamp 1 microcontroller module. It was ready to run, complete with a 5V power supply, an easy variant of BASIC (pre-programmed PIC), an EEPROM for program storage, and even a brown-out circuit to keep things working under nasty conditions. Today, there are many modules and platforms from a variety of vendors, including my Propeller Platform that a few people still sell. Parallax jumped into the mix as well with a very low cost platform — the QuickStart — and it's now a part of my arsenal. It should be in yours, as well.**

The QuickStart PCB (as seen in **Figure 1**) packs a whole lot of power into a diminutive piece of hardware — the board measures just two inches by three inches; it is, in fact, smaller than a standard business card. Within this space is the Propeller chip, a 64K EEPROM (32K for program space, 32K for user space), a 5 MHz crystal, a USB interface (that can power the board), a 3.3V power supply, eight LEDs, and eight "touch" pads which use the resistance of your finger to provide a button input.



■ **FIGURE 1.** QuickStart PCB.

At the risk of being overly blunt, many retailers are just plain lazy and don't know what to do with the QuickStart, so they overcharge for it. I was in a local electronics retailer over the weekend and found it priced at \$43! Even with shipping, you're better off buying directly from Parallax at just \$25.

The idea behind the QuickStart is two-fold: First is to provide a reference design and evaluation tool for professionals (if you are willing to prove you're a pro, Parallax will provide your first QuickStart at no charge — see [www.parallaxsemiconductor.com](http://www.parallaxsemiconductor.com)). The second idea, of course, was to provide a low cost platform for experimenters; a platform that one could use with minimal fuss. I'd suggest that last statement is true; one needs only to connect the QuickStart to a USB port and open a programming tool. With eight LEDs and eight "button" inputs, you can start playing within minutes of removing the QuickStart from its packaging. I think this is where many miss an important bit of information before starting:



On the box the QuickStart comes in is a link to the starter page for it: [www.parallax.com/quickstart](http://www.parallax.com/quickstart).

To be fair, all websites are living entities; none of them are perfect, and this one could stand a bit of updating (which, I'm told, is in the works) — but it's still loaded with a lot of great information for those that have never used the Propeller. It mentions two tools: 1) The Propeller Tool which was written by Parallax and runs in Windows (and emulators), and 2) BST (Brad's Spin Tool) which is a cross-platform clone of the Propeller Tool. BST hasn't been updated in quite a while and nobody is quite sure of its future except, perhaps, the use of its command-line compiler (BSTC) that is very popular with hardcore developers.

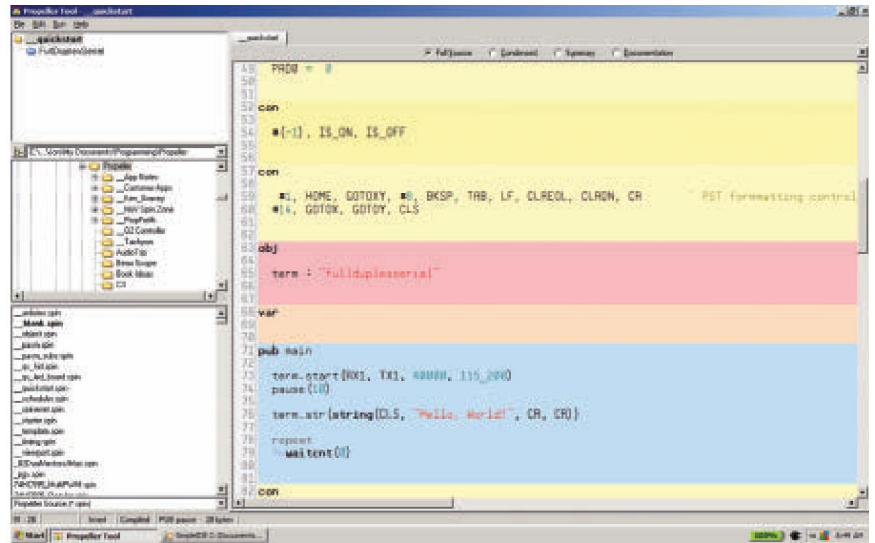
What is sure, however, is Parallax's commitment to a cross-platform tool for the Propeller. Regular readers will remember I mentioned a cross-platform tool being developed by Parallax called SimpleIDE. In fact, SimpleIDE uses BSTC for compilation which allows for the removal of unused methods, shrinking the actual size of code downloaded into the Propeller chip. BSTC may ultimately be replaced with another compiler — one that can support the Propeller 1 and Propeller 2 (nearing completion of development) chips. Even if this happens, it will be transparent to SimpleIDE users.

If you can run Windows, the easiest route is using the Propeller Tool. It is annoyingly missing standard GUI features (toolbar), but it does get the job done. Plus, a popular feature is the color highlighting of code blocks. **Figure 2** shows the Propeller Tool with a section of my template for the QuickStart displayed.

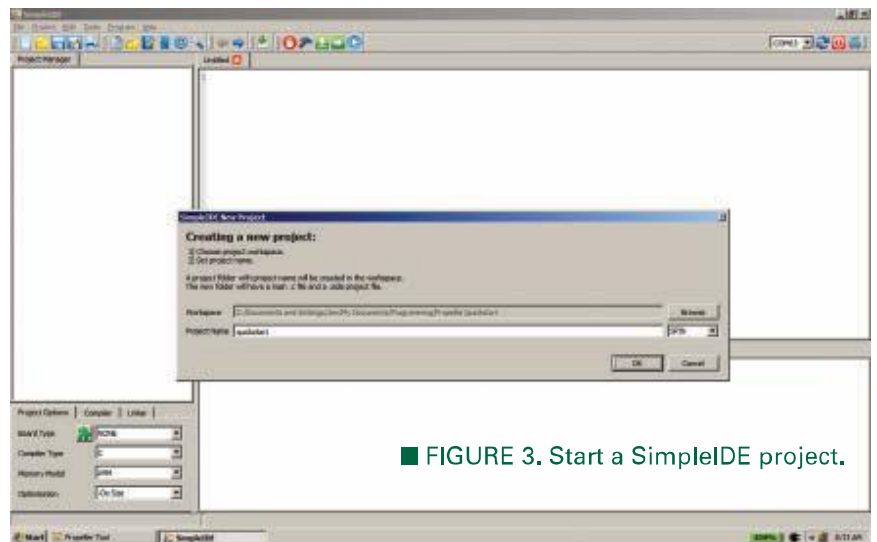
If you'd like to give SimpleIDE a shot, be sure to download the latest update for your favorite OS from this link: <https://code.google.com/p/propide/downloads/list>. As I write this, the latest update is 0.8.5.

Note that SimpleIDE was originally designed for the PropGCC compiler. It turned into such a nice tool that many of us asked that it ultimately replace the Propeller Tool; this would give Propeller programmers a very nice cross-platform multi-language tool. As such, SimpleIDE is project based, even for very simple (single file) applications.

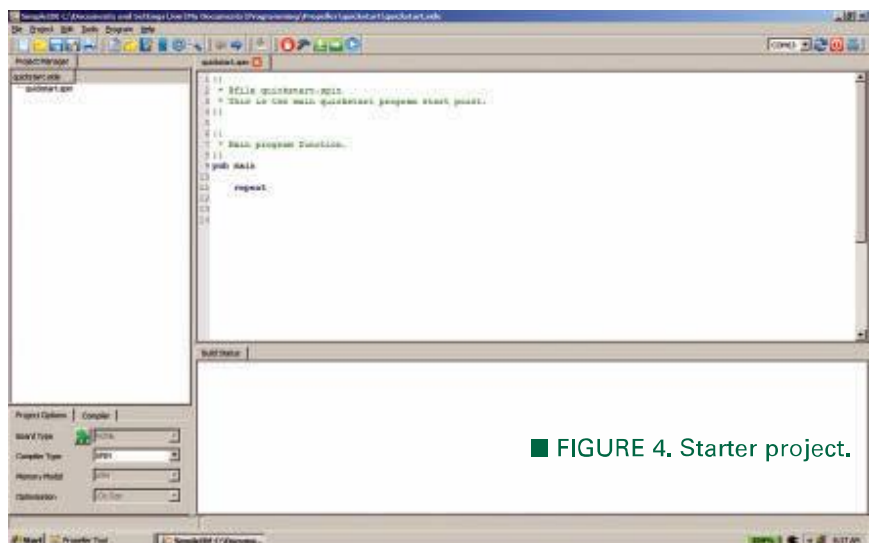
Select **Project/New Project** and use the drop-down in the New Project dialog to



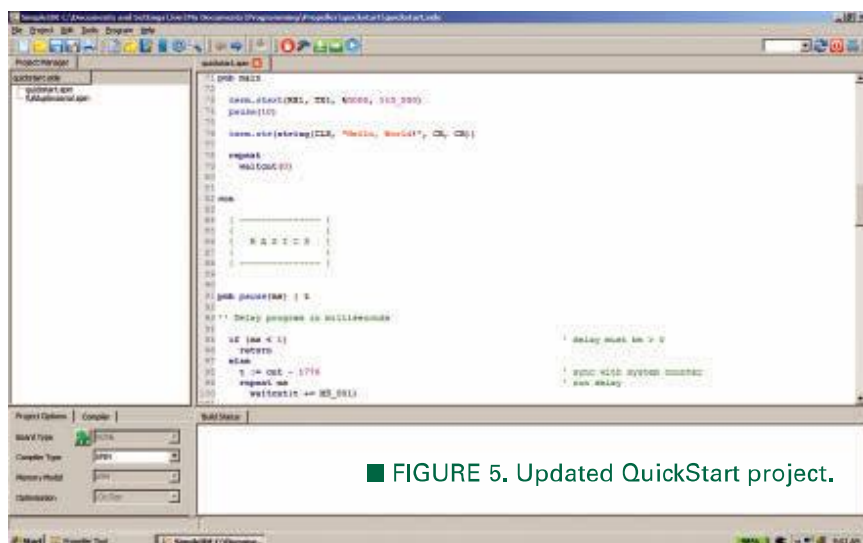
■ FIGURE 2. The Propeller Tool.



■ FIGURE 3. Start a SimpleIDE project.



■ FIGURE 4. Starter project.



■ FIGURE 5. Updated QuickStart project.

select SPIN (Figure 3). The result of this process will be a folder, a project file (.side), and a starter Spin file of the same name (Figure 4).

I already had template code for the QuickStart, so I did a copy-and-paste from the Propeller Tool into the *quickstart.spin* file in my SimpleIDE project. My template file specifies the use of the FullDuplexSerial object/library. By pressing F9 (build), this object was automatically added to the list in the project file (Figure 5). This is a nice feature of SimpleIDE and saves us the trouble of project updating when we use existing code.

For the rest of this column, I will be using the Propeller Tool as it's a little easier for beginners. That said, if you cannot run the Propeller Tool in your OS, then SimpleIDE is there for you — you just won't have the fancy background highlighting.

I'm a very strong believer in the use of templates, so I created one for the QuickStart board (*\_\_quickstart.spin*). Note that my template files — when using the Propeller Tool — start with a double underscore; this lets me know it's a template and sorts templates to the top of the files list as you can see in Figure 2. The primary goal for a template is to define I/O pins particular to a board/project, and define methods for them.

The QuickStart has eight LEDs and eight pseudo-button inputs. Those I/O are spelled out in a CON block, along with the terminal/programming and I<sup>2</sup>C connections which exist for all Propeller applications:

```
con

RX1  = 31
TX1  = 30

SDA  = 29
SCL  = 28

LED7 = 23
```

```
LED6 = 22
LED5 = 21
LED4 = 20
LED3 = 19
LED2 = 18
LED1 = 17
LED0 = 16
```

```
PAD7 = 7
PAD6 = 6
PAD5 = 5
PAD4 = 4
PAD3 = 3
PAD2 = 2
PAD1 = 1
PAD0 = 0
```

My first embedded controller was the BASIC Stamp 1, so I have been using instructions like **HIGH**, **LOW**, and **PAUSE** for a very long time. These instructions do not exist in the Propeller — but that doesn't prevent us from adding them. In all of my templates, I have the following methods which make basic I/O and simple timing a breeze:

```
pub pause(ms) | t

if (ms < 1)
  return
else
  t := cnt - 1776
  repeat ms
    waitcnt(t += MS_001)

pub high(pin)

outa[pin] := 1
dira[pin] := 1

pub low(pin)

outa[pin] := 0
dira[pin] := 1

pub toggle(pin)

!outa[pin]
dira[pin] := 1

pub input(pin)

dira[pin] := 0
```



```
return ina[pin]
```

Just a note for you Arduino lurkers (*I know you're out there, dying to try the Propeller but comfortable with the code you've already written*): A Propeller forum regular named Perry has created a library of methods — similar to what I've done above — that allow you to do most of the things you do with the Arduino now on the Propeller. To get the latest update, do a search for 'Arduino' on the Propeller Object Exchange.

Please keep in mind that the Propeller processor and the Atmel processor used in Arduinos are very different beasts, so it's not going to be perfect. Still, Perry's shown that it's a pretty simple task to port many programs to the Propeller with this library. Once you go multi-processor, you may never go back!

There are two additional methods in my QuickStart template. The first allows us to set all of the LEDs at once:

```
pub set_leds(ledbits)

outa[LED7..LED0] := ledbits
dira[LED7..LED0] := %1111_1111
```

Easy peasy! Move the pattern in *ledbits* to the pins using the **outa** register, then make those pins outputs by setting the bits in the direction register to 1s.

The next method — used to read the button pads on the QuickStart — is a little more involved. The buttons are not actual mechanical buttons, they are simply pads with a break; one side connects to the Propeller pin, another connects to ground:

```
pub read_pads

outa[PAD7..PAD0] := %1111_1111
dira[PAD7..PAD0] := %1111_1111
dira[PAD7..PAD0] := %0000_0000
waitcnt(cnt + (clkfreq / 100))

return !ina[PAD7..PAD0] & $FF
```

The first two lines of this method set all of the pad pins to outputs and high. This charges the parasitic capacitance of the pins. The pins are returned to input mode (to allow discharge) and a 10 ms delay is inserted. This gives the pin time to discharge through a fingertip, but not enough time to do it on its own. As 'touched' pads will read as 0, the bits are inverted (so, 1 = touched), trimmed, and then returned to the caller.

This code is a translation of the PASM code for this process available on the Parallax semiconductor website. Though it worked right off, I wondered about the timing. The great thing about the Propeller — and something I've demonstrated many times — is that it can time itself. I was curious about the 10 ms selection, so I wrote a program

that would charge the pads and time the duration for self-discharge. The result was 30 to 80 milliseconds, so it seems that 10 ms is a good choice — enough time to discharge the pin through a fingertip; not enough for the pin to fully discharge on its own.

A word of caution about the button pads: The I/O pins used are protected with 100K resistors but if you find yourself filled with static electricity (zapping yourself on every doorknob you touch), you'd probably want to discharge yourself before touching your QuickStart button pads.

In addition to the template, I've created a few demo programs for you to play with. If you have a QuickStart that is waiting for some action, give these simple programs a try. Once you understand them, change them, build on them, and then do your own thing.

Another good point about the Propeller Tool is that the Help menu includes all the relevant Propeller documentation, including the text of the Propeller Education Kit. Now, this is a big kit with lots of parts, and the text does a good job of explaining Propeller programming fundamentals. For some real fun, you may want to augment your QuickStart with a Human Interface Device (HID) board — this will let you explore advanced I/O including mouse, keyboard, composite video, VGA, audio, microSD card access, and IR in and out. If you're into networking, Parallax recently created a Wiznet add-on for the QuickStart.

## CREATING A CUSTOM ADD-ON

If you're like me, there will come a time when you want to create your own QuickStart add-on. For many one-offs, there is a QuickStart prototyping board that facilitates adding custom circuitry to the QuickStart.

**Figure 6** shows the pinout of the QuickStart expansion header. Most pins are self-evident, but there's a few that are worth discussion.

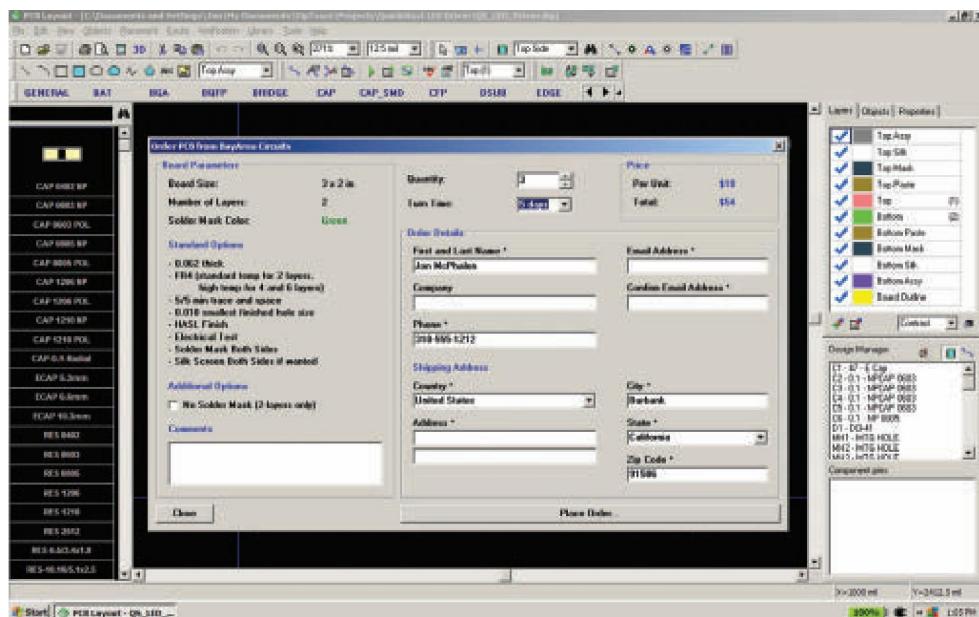
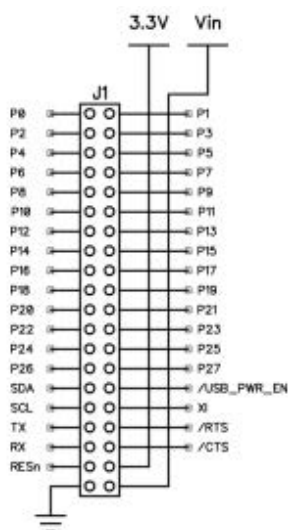
### RESOURCES

**JON "JONNYMAC" MCPHALEN**  
[jon@jonmcphalen.com](mailto:jon@jonmcphalen.com)

**PARALLAX, INC.**  
**Propeller chips and programming tools**  
[www.parallax.com](http://www.parallax.com)

**ALL ELECTRONICS**  
**Miscellaneous tools**  
[www.allelectronics.com](http://www.allelectronics.com)

**ZEPHYRTRONICS**  
**Solder paste and SMD tools**  
[www.zeph.com](http://www.zeph.com)



The **/USB\_PWR\_EN** pin can be used as an input or an output. When reading this pin, a low indicates that the USB interface is connected and communicating with the host. On the QuickStart, this line is used to switch the USB 5V power through a MOSFET to the 3.3V regulator. By exerting 5V on this line, you can shut off that MOSFET. I don't find this necessary, though, as routing 5V (or higher) to the Vin pin causes a Schottky diode that is inline between the MOSFET and the regulator to be reverse biased.

The **XI** pin allows you to provide an external clock source to the Propeller. Before doing this, though, you'll need to remove resistor R13 from the QuickStart to disable the onboard 5 MHz crystal.

The **/RTS** and **/CTS** pins are not connected to the Propeller; these come from the FTDI USB interface and can be used when hardware flow-control is required.

The **RESn** pin is used to reset the Propeller. If you want this capability from a custom add-on, you can pull this line low through an NPN transistor or through a normally-open pushbutton to ground.

## TEMPLATES ARE FOR PCBS, TOO!

I mentioned that I like using templates — this applies to PCBs, too. Some time after switching over to DipTrace, I downloaded the QuickStart files from Parallax and stripped them to the bones. For my QuickStart shields, I open the templates and then use **File\SaveAs** to my project name. After saving, I link the new files by using **File\Renew Design From Schematic** in the PCB editor.

After finishing my schematic, assigning patterns, and double-checking everything, I save the schematic, go back to the PCB editor, and use **File\Renew Design From**

**Schematic** again. Bam! All of the parts from my custom design are there, ready for me to place and route. By using the template, I know the I/O connector and mounting holes are right where they should be.

For those of you who love ExpressPCB (okay, I still love it too, I just find it somewhat limiting for what I'm doing these days), DipTrace has recently been updated to make the process of ordering a board much simpler.

In the file menu, you'll find **Order PCB** brings up the dialog you see in **Figure 7**. DipTrace uses Bay Area Circuits and I have found the price, turn-around, and quality excellent. For small items, I use this feature; for bigger projects or where I need something else (like blue PCBs for the project I describe below), I use Gold Phoenix PCB.

Important Note: The QuickStart PCB template that I've provided is right out of my computer and as such has my name in the bottom solder mask layer — please delete or change this to your own name before ordering PCBs!

## EASY BAKE QUICKSTART SHIELDS

Last year, I put on my big boy pants by stepping up to a professional level PCB development suite. This year, I started making SMD PCBs. There was a discussion in the Propeller forums about low volume SMD production and a member suggested that the Cuisinart TOB-155 toaster oven was a great solution for home SMD fabrication; he even provided a recipe for "baking" boards.

The opportunity to go full tilt came through my friend Steve Wang and his team at Biomorphs who were building another display for Riot Games. The major lighting animation is controlled using two EFX-TEK HC-8+ controllers, but there are a lot of small elements not



connected to the main display that needed animation, as well.

I created a QuickStart shield that is actually a collection of simple circuits:

- Four medium current low side drivers
- Two low current push-pull drivers
- An I/O point with 3.3V to 5V translation
- A microSD socket

To be honest, none of these circuits are remarkable — they just happen to work well together for this project, and some things I anticipate doing down the road.

After double-, triple-, and quadruple-checking everything, I exported the Gerber files for my shield (called the QuickStart LED Driver) and sent them off to Gold Phoenix PCB. I wanted blue solder mask to match the QuickStart and paid an extra \$20 for it. It's a good deal. For about \$140, I got 25 PCBs. Yes, there are a couple of steps when using Gold Phoenix, but it's really hard to argue with the price and quality.

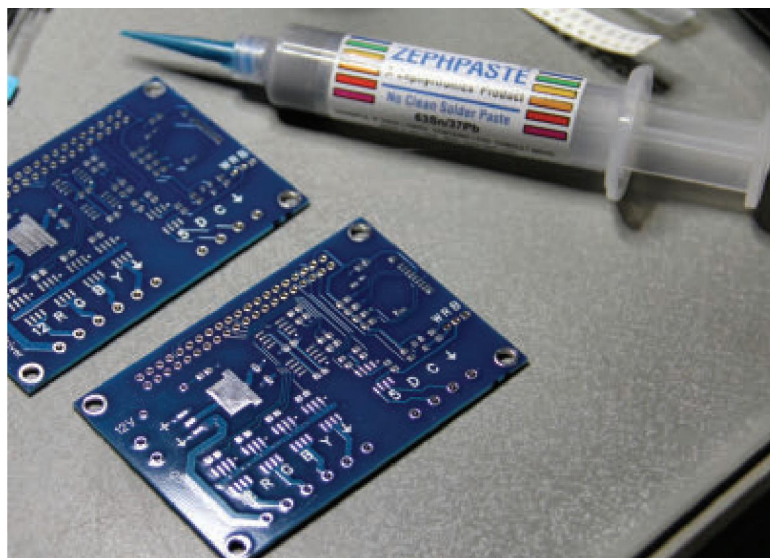
I have two friends (Rick and John) that have the TOB-155 toaster oven. Rick lives close and said I could borrow his oven any time. John lives on the other side of the country but solders a lot of surface-mount PCBs in his oven, hence I wanted to turn to his experience.

My writing is typically about how to code, not how to build — so this is a little different. I'm going to explain the steps to fabricating my QuickStart LED Driver. These steps are based on talking with those that have far more experience than me. In the end, the process was easier than I expected, and I was able to produce very nice boards. Here we go.

Step 1 is to clean the PCBs with 99% alcohol (don't use rubbing alcohol). Dirt and grease are bad — always. **Figure 8** shows my cleaned boards, ready for paste. BTW, I picked up some nifty parts trays at All Electronics for less than a dollar each. They're anti-static and have a lip around all the edges which help keep small parts from wandering away.

Step 2 is to apply the solder paste. John gets stencils made and goes that route. This PCB was my first attempt at SMD production and I was trying to keep things simple. To that end, I ordered a syringe of paste from Zephyrtronics. By using a light touch with the syringe, under good light and with a magnifier in the other hand, I was able to place the paste pretty quickly. Keep in mind that you don't need a lot of paste on a pad, and it's best to keep things as neat as you can during the process. Just as you wipe the tip of a soldering iron to keep it clean, I found it best to wipe the tip of the syringe from time to time to keep solder paste going where I wanted it to go.

In **Figure 9**, you can see my reasonably neat



■ **FIGURE 8.** Ready for paste.

little solder paste blobs on the pads. Remember, solder paste is a combination of flux and solder — there's not as much solder there as you think.

Step 3 is to place the parts. Another useful find at All Electronics was a pair of wickedly sharp tweezers; these are perfect for the job. Again, I did my best to keep things neat — there's no sense smearing paste around that could form bridges between legs on an IC. **Figure 10** shows parts set carefully into the paste.

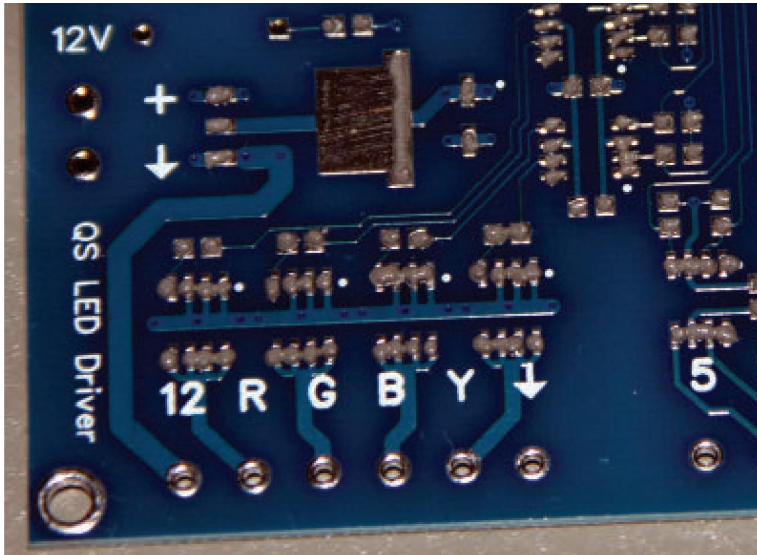
Yes, it does look like bridges are going to form between the legs; they usually don't unless there's just too much paste. On this board, I did have one small bridge which was easily corrected with a fine-tip soldering iron, but it was not in the area of the photo.

Step 4 is to check and adjust parts alignment. I use a dental pick.

Step 5 is to bake the boards. Again, my friend John

## PARTS LIST

ITEM	DESCRIPTION	SOURCE
C1	22 $\mu$ F	Digi-Key PCE3953CT-ND
C2-C6	0.1 $\mu$ F	Digi-Key 490-1726-1-ND
D1	1N4001	Digi-Key 1N4001DICT-ND
Q1	BSS123	Digi-Key BSS123NCT-ND
Q2-Q5	FDS6612A	Digi-Key FDS6612ACT-ND
R1-R12	10K	Digi-Key P10.0KCCT-ND
R13-R16	25.5	Digi-Key P25.5CCT-ND
SD1	DM3D-SF D	Digi-Key HR1941CT-ND
TB1-TB6	0.2" x 2	Digi-Key 277-1247-ND
U1-U3	TC4427	Digi-Key TC4427ACOA713CT-ND
VR1	LM1084IS-5.0	Digi-Key LM1084ISX-5.0/NOPBCT-ND
X1-X2	0.1" M HDR	Digi-Key S1012E-36-ND
PCB		<b>GoldPhoenixPCB.com</b>
QuickStart		Parallax 40000
Nut (4x)		Parallax 711-00005
Standoff (4x)		Parallax 713-00023
Screw (4x)		Parallax 700-00047



■ FIGURE 9. Paste applied.

- Bump temperature to 400 degrees until just after re-flow.

When the boards are done, turn the oven off and very gently open the door. Let the boards cool for about 30 seconds before — also very gently — pulling the rack out to complete the cooling. If you get too aggressive with the rack before the solder has cooled, you could find that parts shift, possibly ruining your hard work. **Figure 11** shows my board with just a couple little solder balls that are easily removed with a dental pick.

John explained that the first step helps drive any moisture out of the parts and helps big components like the regulator get some heat into them. The second stage is actually the first part of the re-flow profile. Finally, the last stage heats the PCB and solder enough for re-flow. John warned me not to leave the boards in the oven very long after re-flow; if the PCBs get too hot they can scorch and de-laminate. Using his recipe, I never had this problem and all of the boards turned out really great.

has a lot of experience in electronics manufacturing and has "cooked up" many PCBs in his toaster oven, so I went with his recipe for baking:

- Put boards in oven and set to 200 degrees for three minutes.
- Bump temperature to 275 degrees for two minutes.

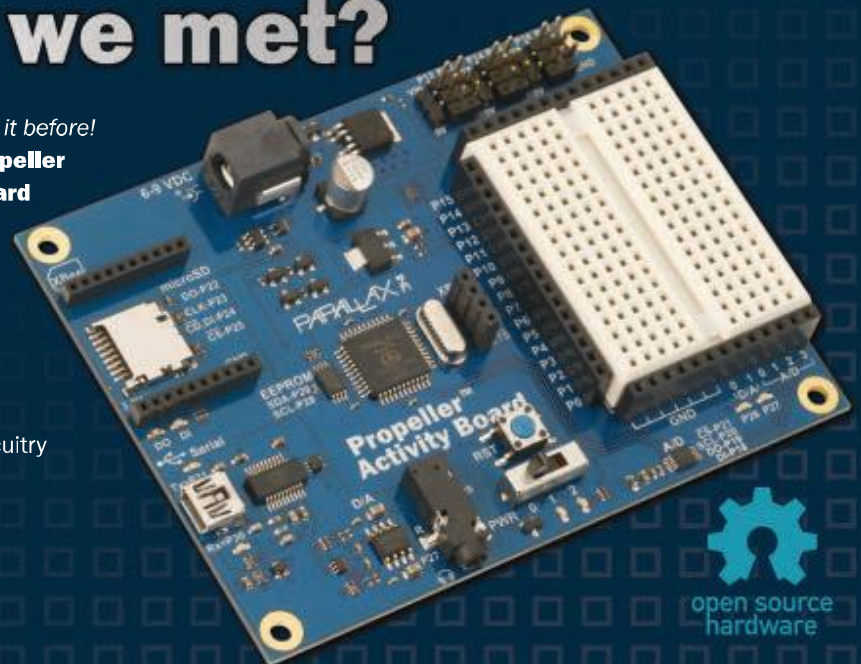
# Hello. Have we met?

*It's the multi-core Propeller as you've never seen it before!*

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- XBee socket
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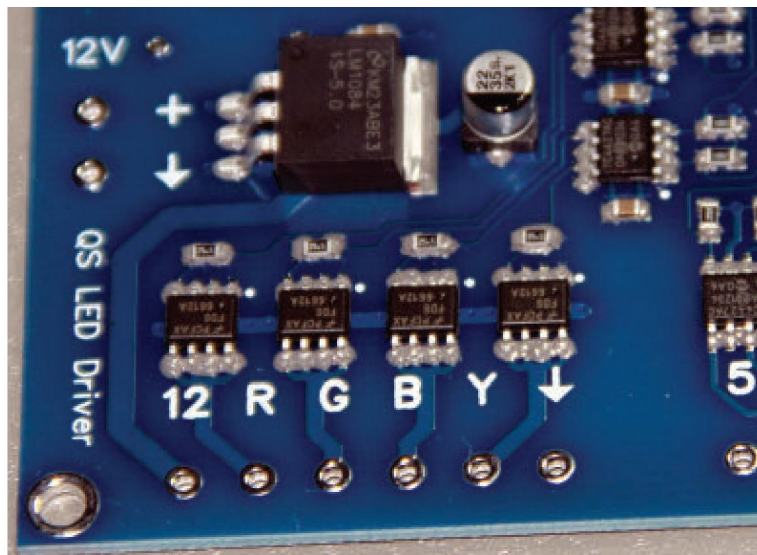
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■ FIGURE 10. Components placed.



I think a lot of people — myself included — shy away from SMD fabrication because it seems like it's going to be very difficult; it really isn't. Another issue is the life and storage of solder paste. One of the things that sold me on the Zephyrtronics paste is that it has a rated shelf-life of six months without refrigeration (one year with refrigeration). I can tell you from experience that they're customer service is very friendly and helpful, too. Still, with companies like Pololu and others offering low cost stencils, I will probably try that for a project that requires more than a couple boards being built. How long did it take? I put together two at a time and could do it from bare board to completion in about an hour. Don't rush, though. The quality is worth the extra time.

Figure 12 shows the completed board with through-hole components mounted to a QuickStart PCB and ready to be deployed. Before I wrap up, let me show you one of the prop elements that used the QuickStart LED driver. In Figure 13, you'll see what looks like an old-school cannonball bomb that is sitting in the ground. If you look

closely you'll see the end of the wick has an orange glow; when seen in person, this appears to be sparking.

A buddy of mine works for Disneyland and taught me how to make this, and it's actually quite simple: Several strands of plastic fiber-optic cable are glued to the end of an LED. We used four LEDs in our case, with three fiber-optic strands each. The fibers are then bundled and the

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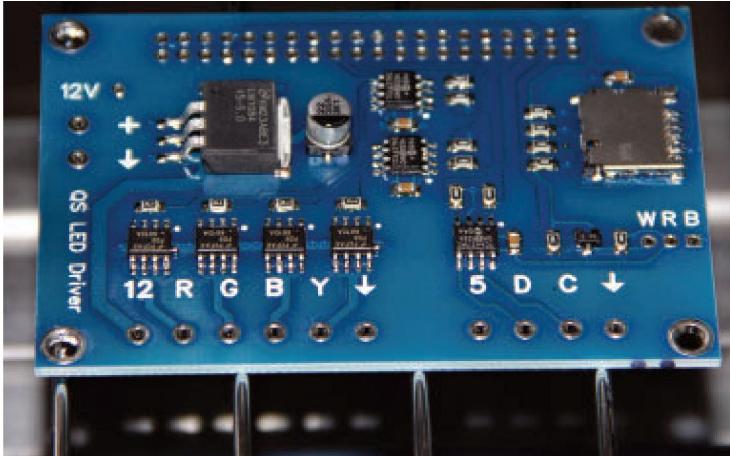
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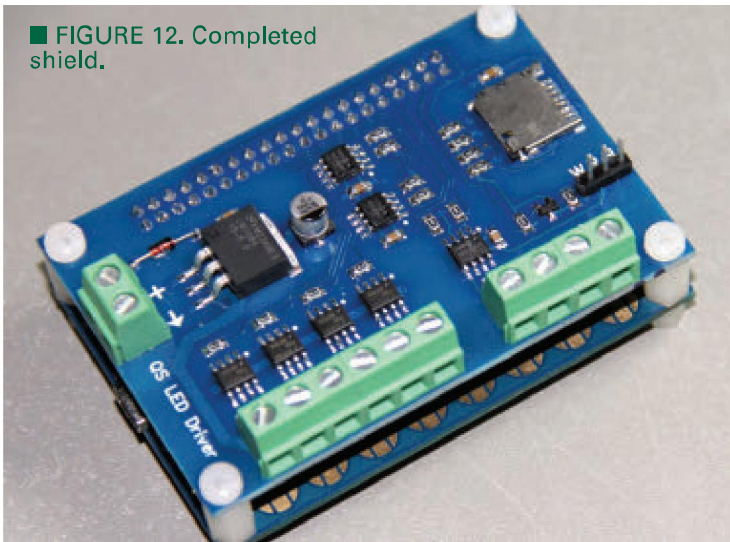
For complete information, visit [HakkoUSA.com/NutsVolts](http://HakkoUSA.com/NutsVolts)







■ FIGURE 11. Finished baking.



■ FIGURE 12. Completed shield.



■ FIGURE 13. Finished prop.

ends randomly placed (with the help of a tester program). The ends of the fibers are painted black to look like ash; the bundle is wrapped in cloth tape to look like a wick. Finally, the ends are cut and trimmed at random angles. The painting and wrapping was another great artistic call by my friend, Mike Deak, and it really sells the effect. By running a random pattern through the LEDs, the wicks appear lit and sparking.

There is a random operator in the Spin language, but many have demonstrated that it's not as random as one would hope. No problem! A forum member translated a popular C algorithm to Spin and it works nicely. For those times when I want to get really crazy, I seed the PRNG (pseudo-random number generator) object with the RealRandom object — that wasn't necessary for a simple trade show display. Here's how simple creating output for the wicks can be:

```
obj

  prng : "jm_prng"

pub main

  prng.start

  dira[PWM_Y..PWM_R] := %1111

  repeat
    outa[PWM_Y..PWM_R] := prng.random
    pause(25)
```

Uh ... yeah, it's really that easy. Start the PRNG object, make the LED pins outputs, then write a random pattern to the LEDs every 25 ms.

Of course, if this was the only thing we had to do, we could have used far simpler hardware, but those props also have WS2801 LED strings in them so that the skull graphic can throb and change colors. There is a TC4427 and stout 5V power supply on the QuickStart LED driver board specifically for this task.

Well, that's a wrap. If you're new to the Propeller and haven't cracked open your QuickStart yet, jump on it! You're just delaying having fun. If you've thought about making your own QuickStart shield, well, just do it. There's a bit of a movement with users creating custom QuickStart shields; Jeff Ledger ([www.propellerpowered.us](http://www.propellerpowered.us)) has some nice boards, and Ray Allen ([www.rayslogic.com](http://www.rayslogic.com)) has some really neat stuff, too.

In fact, next time we're going to jump into Ray's QMP (Quick Media Player) shield and I'll share my secret for playing high quality WAV files with the Propeller.

Until next time, then, keep spinning and winning with the Propeller! **NV**



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## Garbage and Recycling Reminder Kit

Easy to build kit that reminds you when to put which bin out by flashing the corresponding brightly coloured LED. Up to four bins can be individually set to weekly, fortnightly or alternate week or fortnight cycle. Kit supplied with silk-screened PCB, black enclosure (83 x 54 x 31mm), pre-programmed PIC, battery and PCB mount components.

- PCB: 75 x 47mm

Cat. KC-5518

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## Jacob's Ladder MK3 Kit

A spectacular rising ladder of bright and noisy sparks for theatre special effects or to impress your friends. This improved circuit has even more zing and zap than it's previous design from April 2007 and requires the purchase of a 12V ignition coil (available from auto stores and parts recyclers).

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- Powered from a 12V 7Ah SLA or 12V car battery.

Cat. KC-5520

**\$36.00\***

Battery not included



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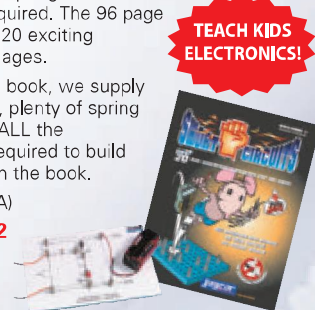
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# QUESTIONS & ANSWERS

■ WITH  
RUSSELL KINCAID

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: [Q&A@nutsvolts.com](mailto:Q&A@nutsvolts.com)

## SYNTHESIS CIRCUIT

**Q** I am building an RF receiver using an LC sinewave oscillator. I intend to use Si570 as the main frequency control; it is a programmable DSPLL crystal oscillator. I have the low voltage differential signaling IC which covers 3.6 MHz to 260 MHz. The first IF is 10.7 MHz; the second IF is 455 kHz. The receiver has 12 bands, and varicap tuning is used in all the tuned circuits in the AE/RF/Oscillator sections.

The varicap tuning range voltage is two to 10 volts. I want to use the AD9901 IC as the PLL; the oscillator output is 0.5 VRMS sine wave. Do you think it will work if I feed the 0.5 VRMS to the AD9901 pin 5? Or, do I have to step it up and change to a square wave?

No frequency dividers are used. I appreciate and follow your monthly advice to *Nuts & Volts* readers. Thanks for your help.

— Charlie Fenech

**A** This looks to be an ambitious undertaking. To answer your question; no, it won't work with 0.5 VRMS input. The input requires TTL levels: 2.4V minimum for high; one volt max for low.

Unfortunately, I can't help you with the design; I am not familiar with modern receiver design. You didn't mention the I<sup>2</sup>C digital signal needed to tune the Si570, but that has to be considered.

## IC CHIP QUESTION

**Q** I have acquired some IC chips, brand new in the package. I researched the Internet to find info with no luck. There are two packages: The first one has the ID 51-82848m48 anti-static ACU on the package. On the back is RPX-4443A BA in a Motorola package. The second IC (still in the original Motorola package) shows 5180379a58 anti-static ACU; nothing on the back. Any info will be appreciated.

— Jim Houser WA8JIM

**A** I don't recognize these numbers as any kind of IC. You say these numbers are on the packaging; is there anything on the IC itself? There should be an ID and a four digit number indicating the month and year of manufacture. If there is nothing on the IC, throw them away because they are rejects that did not make it to the marking process.

## GROUNDING PROBLEM

**Q** Our children recently gave us a Samsung 39" TV which has no RCA audio output jacks to drive my grounded stereo system. Across each of the TV's stereo speakers, I attenuated the signal with two resistors in series — 100 ohm and 10 ohm — taking the audio from across the 10 ohm resistor from each stereo side to a pair of RCA jacks just outside the TV. When I connected

my audio system that has a common ground to the stereo jacks, I got a white noise sound but no 60 cycle hum. After checking, there appeared to be a small 100 mV AC signal between the stereo grounds of the TV, with no connection to my audio system being made. No DC voltage was observed. If only one channel is connected to my audio system, all works well.

Is there a work-around to give the TV a common ground so I can get both channels to work together? The Samsung TV model is UN39EH5003FXZA. I have not been able to get a circuit diagram of the TV. Why would a manufacturer not want to provide a common ground?

— Ron Straight

**A** I contacted Samsung and verified that there is no way to get audio output except to use the speakers, as you discovered (lousy design, in my opinion). It is common for there to be a small voltage difference between AC grounds — especially if you are measuring from different outlets — because the grounds may be common back at the main distribution panel and the currents in the grounds are different. The speakers in the TV are floating, so Samsung didn't have to worry about common ground.

The solution is to use an audio transformer in place of the 10 ohm resistor. Mouser part #838-MET-31 is 600 ohms, 1:1, rated 50 mW, and costs \$12.60 each. You can connect the transformers in place of the



speakers if you want. You may want to increase the bass boost in the audio system because the transformer is rated 300 Hz to 100 kHz.

## RESISTOR VALUES FOR LIGHT/DARK

**Q** I just finished a sound alarm which was described to be equipped with a photocell, but discovered that it came with a clear phototransistor (LED style: T1 3/4). Instead, I'd like to use a *real* photocell but don't know what ratings (ohm values) I should use (for light and dark).

Can you specify optimum ohm values (dark/light) for such a 'photocell?'

— Nate

**A** You should be able to just wire the phototransistor in place of the CDS cell that was on the schematic. The difference is that the transistor has polarity while the CDS cell does not. The transistor collector goes to positive and the flat on the T1 3/4 package should denote the emitter. If the phototransistor has three leads, leave the base lead open. CDS photodetectors are hard to find; RadioShack does not carry them anymore, which is probably why the phototransistor was substituted.

## POWER SUPPLY QUESTION

**Q** I have a question on an ETASIS redundant power supply model #EFRP-250A. I found a datasheet on their website that mentions TTL compatible signals. Is there any way I can test

this power supply? When I power it up, the LED status turns red; it is supposed to turn green. I assume it has something to do with the way the output connector is wired.

Does the PSON (remote on/off) have to be grounded through a resistor? I'm not sure how to wire it so it powers up. Do you have any ideas or suggestions?

— Jeff Miller

**A** The power supply should turn on when +5V is applied to the PSON terminal. If the status LED is turning red, that indicates there is a fault and the supply needs repair.

## MORE ON THE SYNTHESIS CIRCUIT

**Q** I bought a complete receiver kit which includes the SI570 oscillator, microprocessor, and LCD frequency display; thanks for your answer on the oscillator. Now, my question is: How is the application circuit — shown for ECL (emitter coupled logic) operation — to be modified to work with TTL signals? The output is to be from 2V to 10V to the varicaps.

— Charlie Fenech

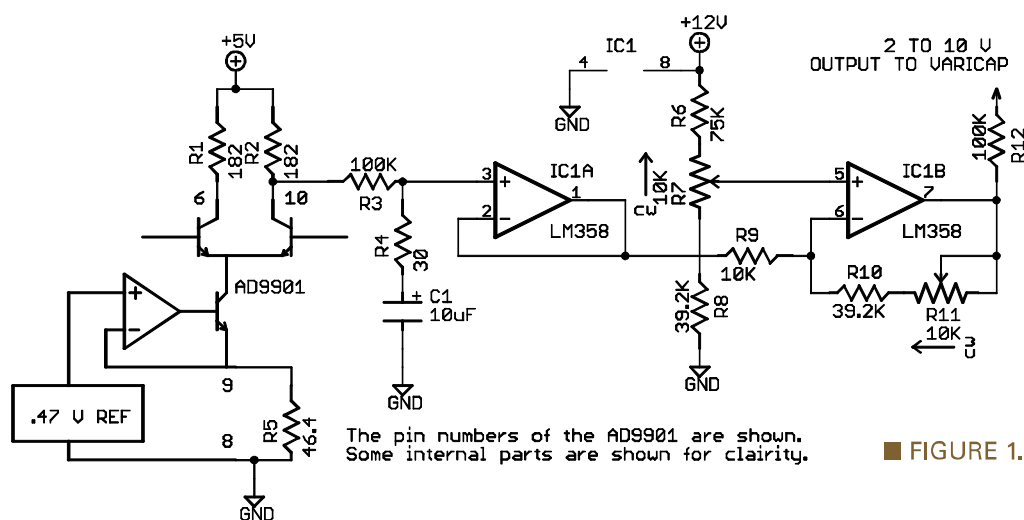
**A** If your circuit is similar to Figure 12 in the datasheet (except when operated from +5V), the connections to the AD9901 and the filter circuit will be as in **Figure 1**. The AD9901 output is from 3.2 to five volts, so there is a large offset which has to be adjusted out via R7. The signal to the varicaps is eight volts p/p and the AD9901 output is 1.8 volts, so the required gain is  $8/1.8 = 4.44$ .

The gain can be adjusted with R11; the controls don't interact, so the adjustment will not be difficult. The RF filter can only have one capacitor or the loop will be unstable. The series resistor is for loop stability and I assume that the 30 ohms used in the datasheet is okay.

## KODAK PHOTORESIST AND DEVELOPER

**Q** In your answer to "making circuit boards," you mentioned using pre-sensitized copperclad board that can be exposed using ultraviolet light. My question is: What ever happened to Kodak photoresist and developer where you made your own sensitized boards? I can't find it listed anywhere.

— William E. Kenyon



■ FIGURE 1.



**A**KPR (Kodak photo resist) is available from Photofabrication Chemical & Equipment Company, 522 Lancaster Ave., Malvern, PA 19355; phone number is 610-296-8585. I don't know how old this information is, but KPR (part number MP-111) is \$95 per quart.

The developer (MP-142/61) is \$92 per gallon.

You can get UV curable positive photoresist from Injectorall Electronics Corp. Two ounces (part number PC197-2) is \$44.49. Their address is 110 Keyland Ct., Bohemia, NY 11716; the toll free phone number is 800-878-7227.

If you are not making a large board (larger than 6 x 9); it seems to me that it is better to buy a pre-sensitized copperclad board; 6 x 9 for \$12.46 or 3 x 5 for \$6.95; Mouser part numbers are 590-612 and 590-603, respectively. A 4 x 6 and 6 x 6 are also available. Phone number is 800-346-6873. **NV**

## MAILBAG

### Re: Voltage Converter question, January 2013, page 24.

Most PLCs have a variety of input cards and output cards. Typical Allen Bradley PLC Family and Reliance AutoMax/DCS 5000 had these available, along with lots of other cards. If I remember correctly, we used the AB 1775 series cards, but they have gone to block I/O and

smaller distributed I/O now.

There is more information at [www.plcs.net/dcforum/DCForumID1/2645.html](http://www.plcs.net/dcforum/DCForumID1/2645.html), [www.plcs.net](http://www.plcs.net), and [www.plctalk.net/qanda/showthread.php?t=22644](http://www.plctalk.net/qanda/showthread.php?t=22644).

Most 24 VDC inputs need 10 mA of current through the input card to make sure it's turned on.

Larry Kraemer

*Thanks for writing, Larry. I forwarded the full email to Al Bochter, but abbreviated it for publication here. Interested readers can visit the links that you provided.*

### Re: Voltage Converter question, January 2013, page 24.

I see no diode on the input to the opto-isolator! The signal is

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reduced in voltage, but the 60 Hz AC is being passed through the opto-isolator and is turning on-off the 2N2222A transistor. Removing the C3 capacitor will actually worsen the problem. PLC inputs are optically coupled and have an average response of 1-5 kHz; 60 Hz will definitely turn on/off the input. There are parameters that can be adjusted to limit input frequency response, but none that reject 60 Hz. I recommend he install a half wave rectifier at the R3-C2 top junction pin 1 side; (1N4004), C2 = 47  $\mu$ F. This should get a +only DC input to the H11AA1. PLC inputs are in the 1-10 mA range.

Rich Wright, Senior Design Eng.

*Since I knew nothing about PLCs, I appreciate your feedback. I*

*forwarded your email to Al Bochter. Thanks for writing.*

**Re: NiMH Battery Charger, February 2013, pages 24-26.**

You say that the battery temperature is used to indicate full charge. I have some questions: What causes the battery to heat up during charging? And, why do you resume the charging after the battery cools down if it is already charged?

Sam Botros

*Thanks for the questions. The battery temperature does not rise during charging; it starts to rise when it is fully charged. The reason is that it starts to generate gas which could cause it to explode, so the manufacturer puts in a catalyst that causes the gas to re-combine. That is*

*an exothermic process, so the battery heats up. The charging resumes when the voltage drops, and when it cools down. The battery is charged to over 100% when the charging stops and starts charging when the charge drops to 100% (due to internal leakage), so it is always at least fully charged.*

**Re: Bench Top Power Supply, January 2013, pages 24 and 25.**

Ed (no last name) writes to say that R2 in Figure 2 could be a 25 ohm five watt pot instead of the 50 ohm 12.5 watt pot that I specified, at lower cost. Digi-Key part CT21152-ND is \$4.63. The same model pot could be used for R4.

*Thanks for the input, Ed.*

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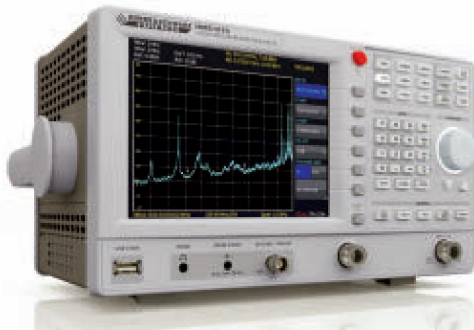
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instrument with the new performance.

This added value applies not only to new instruments, but to all products delivered since July 01, 2012. Equipment has been tested at the factory to ensure compliance with the new specifications, and can be upgraded accordingly.

The free upgrade to 1.6 GHz is also available for all HMS1000 products purchased prior to July 01, 2012. This is subject to the restriction that these instruments could not be tested at the factory to guarantee compliance with the expanded frequency range.

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**B**&K Precision has expanded its digital storage oscilloscope (DSO) portfolio with the release of their new 2550 Series. This new series of scopes adds four two-channel models (2552, 2554, 2556, 2558) and four four-channel models (2553, 2555, 2557, 2559), ranging from 70 MHz to 300 MHz bandwidth with 2 GSa/s sampling rates and 24 kpts/Ch memory. These high performance digital oscilloscopes cover a wide range of applications in R&D, service and repair, and education at a cost-effective price point.

While maintaining a portable form factor, the 2550 Series introduces a significant increase in display size compared to typical 5.7" displays on economy scopes. The new models feature a widescreen 7"



TFT color display that maximizes visibility of signals under test, which is a benefit for long waveform captures or four-channel acquisition.

All models in the 2550 Series offer powerful debugging tools such as digital filtering with adjustable limits, waveform recorder mode, pass/fail testing, advanced triggering capabilities, 32 automatic measurements, and a large internal storage for saving and recalling up to 20 different waveforms and 20 oscilloscope setups. The scopes can also perform five waveform math functions: add, subtract, multiply, divide, and FFT. Each DSO comes standard with LAN and USB interfaces supporting SCPI and

USBtmc protocols for remote PC control. The provided PC software allows all scope parameters to be controlled via a PC without the need for programming. At no additional cost, high bandwidth passive probes (one per channel) are also included with each unit; 200 and 300 MHz models add selectable 50 ohm input impedance.

Other useful features include context-sensitive help menus, multi-language interface, and the ability to disable the Auto Set button for training. Front and rear panel USB host ports are provided to quickly save setup and waveform data, screenshots, or CSV files to a USB flash drive. B&K Precision's 2550 Series oscilloscopes are all backed by a standard three year warranty. Prices range from \$1,015 to \$2,495.

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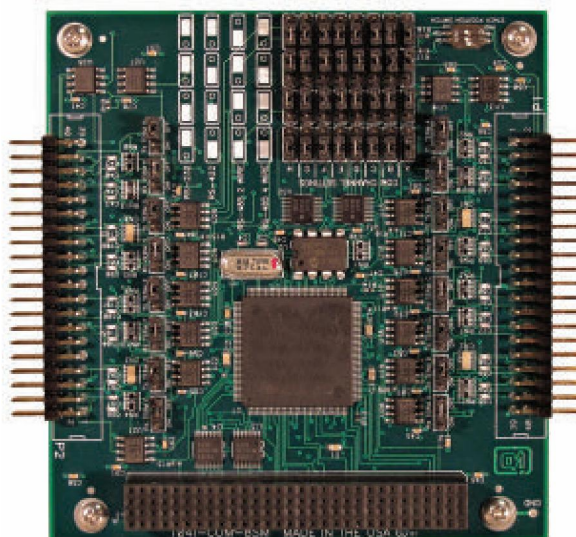


## RS-232/422/485 SERIAL COMMUNICATION BOARDS

**A**CCES I/O Products, Inc., announces the release of a new family of PCI-104 serial communication boards: the 104I-COM-8SM Series. These PCI-104 boards feature a selection of eight, four, or two ports of field selectable RS-232, RS-422, and RS-485 asynchronous serial protocols on a port by port basis.

Ports are accessed via two 40-pin IDC type right angle header connectors. The 104I-COM-8SM Series are feature-rich and allow for the connection of multiple serial devices making them ideal for a variety of applications such as POS, gaming systems, retail, hospitality, automation, kiosks, defense industries, high-density networking, or any other application requiring the connection of RS-232/422/485 serial devices to a PCI-104 compatible system.

Each RS-232 port is capable of supporting data communication rates up to 921.6 kbps and implementing full modem control signals to ensure compatibility with a broad variety of



serial devices. RS-422 and RS-485 modes support data communication speeds up to 1.8432 Mbps. Based on the XR17D158, the boards have eight enhanced 16550 compatible UART and include 64-byte transmit/receive FIFO buffers to decrease CPU loading, and protect against lost data in multi-tasking systems while maintaining 100% compatibility with all operating system COM port software.

ACCES offers the 104I-COM-8SM, 4SM, and 2SM in both standard and extended temperature

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The 10I-COM-8SM family of boards is supported by all operating systems as standard serial ports. All boards include a free DOS, Linux, and Windows XP/Vista/7

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Datasheets and 2D engineering drawings are available on the L-com website. Prices range from \$35-\$63.

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## BEAM ATTACHMENT BLOCKS

ServoCity's aluminum beams have become a popular way to create custom links and connectors, and their new beam attachment blocks introduce even more design possibilities. Like the beams, the attachment blocks are constructed of 6061-T6 aluminum for strength and rigidity. The beams have 6-32 thru-holes that are spaced to be compatible with the 0.770" hub pattern found throughout the ServoCity product line. The beam attachment blocks have one 6-32 tapped hole for mounting the block, and one 6-32 thru-hole for creating links. The photo shows the beam blocks joining ServoCity's new channel to the beams using 6-32 socket head screws and nylock nuts. For a rigid structure using the beams and blocks, tighten the nylock nuts completely. For a movable structure, slightly tighten the nuts. Price is \$4.99/four-pack.



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The newest design kits are the RL-9580-DK1 and RL-9580-DK2, which comprise the entire 9580 series of high current SMD power

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Each series of inductors also boasts a wide operating temperature range of -40°C to +130°C, allowing for maximum performance in any condition. The Designer Kits are only available to registered users on the Renco website at this time.

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## DRIVER FOR WINDOWS 8 ANNOUNCED

ICS Electronics has released their updated GPIB driver for controlling test instruments on Windows 8 operating systems. Designated as 488.2V4, this updated driver fully supports 32- and 64-bit Windows XP, Vista, Windows 7, and Windows 8 operating systems. The 488.2V4 driver provides full support for 64-bit programs with a true 64-bit DLL for executing 64-bit programs. The new driver allows ICS's 488-USB2 USB-to-GPIB controller, the 488-LPCI PCI GPIB card, and the 488-PXI PXI GPIB card to be used in test and measurement applications that are run on PCs with the Windows 8 operating system.

The 488.2V4 driver provides a 64-bit program developer with several advantages. Its 64-bit DLL lets the user run a program completely in the 64-bit address range, instead of converting to a 32-bit DLL. All utilities like ICS' Explorer and GPIBkybd program are installed in both 64- and 32-bit versions.

The 488.2V4 driver will automatically detect the version of the operating system and install the correct lower level drivers and utilities for the particular OS. Its GPIB-32.dll is compatible with other GPIB-32.dlls, and supports programs written with direct dll calls, as well as VISA libraries from Agilent, Kikusui, and National Instruments. The driver is available free of charge to ICS customers.

For more information, contact:  
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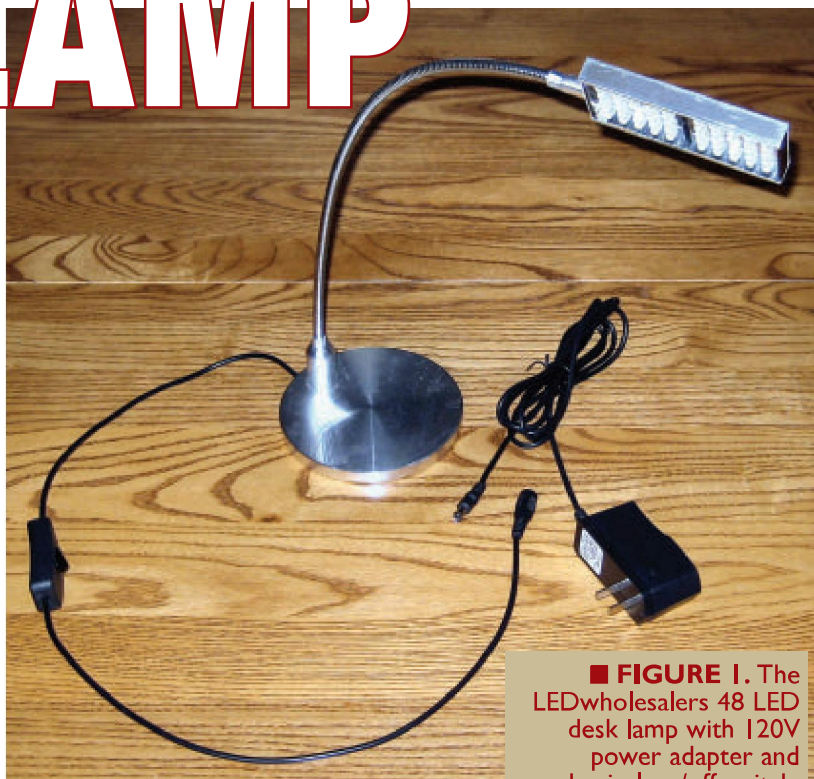




# HACK AN LED DESK LAMP

By Jim Teixeira

A while back, I purchased an LEDwholesalers 48 LED desk lamp (about \$30 from **Amazon.com**). It's not very pretty, but it provides a lot of light over a magazine size area and I use every day as a reading lamp. Early models of the lamp had a touch capacitive on/off switch in the base which proved troublesome, and was replaced with an inline mechanical switch as shown in **Figure 1**.



■ **FIGURE 1.** The LEDwholesalers 48 LED desk lamp with 120V power adapter and mechanical on/off switch.

It occurred to me that the lamp would make a good battery operated emergency light. It comes with a 120 volt power adapter that connects to the lamp with a standard inline co-axial Type N power connector (this is the connector type used in many battery eliminators), so the mechanical connection to a separate power supply would be simple. I made some electrical measurements on the power unit, and found that it is basically a 150 mA current source with a maximum voltage of just over 20 volts unconnected. When connected to the lamp, the voltage was just under 18 volts so the lamp itself draws 2.6 watts ( $18 \times .15$ ); the power source delivers 3.0 watts ( $20 \times .15$ ). Assuming 75% efficiency then, a battery has to deliver about four watts.

I had some additional requirements on the battery power supply: It must have a dimmer control so it could be used at reduced power as a night light; it must have a low battery voltage detector circuit; and it should have at least six hours running time at full light output.

**Figure 2** is a block diagram of the battery power supply. At the top is the voltage converter that boosts the battery voltage to the 20 volts (max) needed by the LED lamp. In the center block is the 150 mA current source with a dimming control. The bottom block is the battery low voltage detector that warns the user of low battery voltage by dropping the current source setting, and

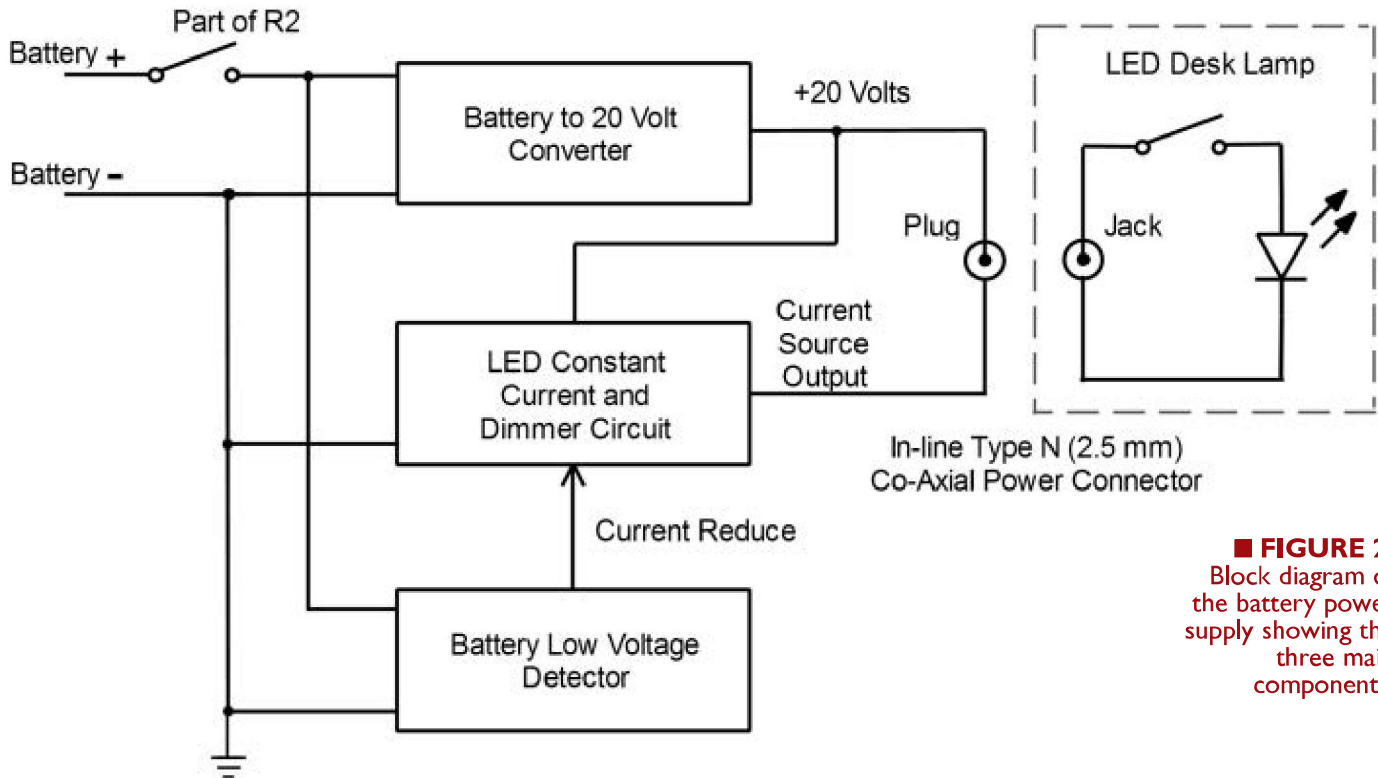
thereby reducing the lamp brightness.

Supplying four watts from a battery for six hours is not a trivial matter. It is 24 watt-hours, so don't think AA Duracell. There is a battery comparison you may find interesting at [www.candlepowerforums.com/vb/showthread.php?64660-Alkaline-Battery-Shoot-Out](http://www.candlepowerforums.com/vb/showthread.php?64660-Alkaline-Battery-Shoot-Out).

I made my own measurements using four D batteries powering the lamp, and got less than four hours of operation. I got a little better time with four D cell NiCad batteries, but these lose their charge faster than most battery types and have to stay on trickle charge. In my experience, this reduces battery lifetime. Another possible battery type is a 12 volt sealed lead acid battery. This is, in fact, a pretty good choice, but I decided to use a rechargeable lithium-ion battery.

I purchased a 12-volt li-ion battery (DC-12680) complete with charger on eBay for about \$20 (comes from China). This battery supposedly has a 6,800 mAh capacity that should supply 20 hours of driving the lamp. I actually measured about six hours when discharged to 10 volts, and about another hour when discharged to nine volts. I don't know where the 6,800 mAh claim came from, unless it was at a very low current draw. There is also a 9,600 mAh version (about \$30) of the battery that should give about 10 hours of operation. These batteries have an on/off switch and a Type M output connector.

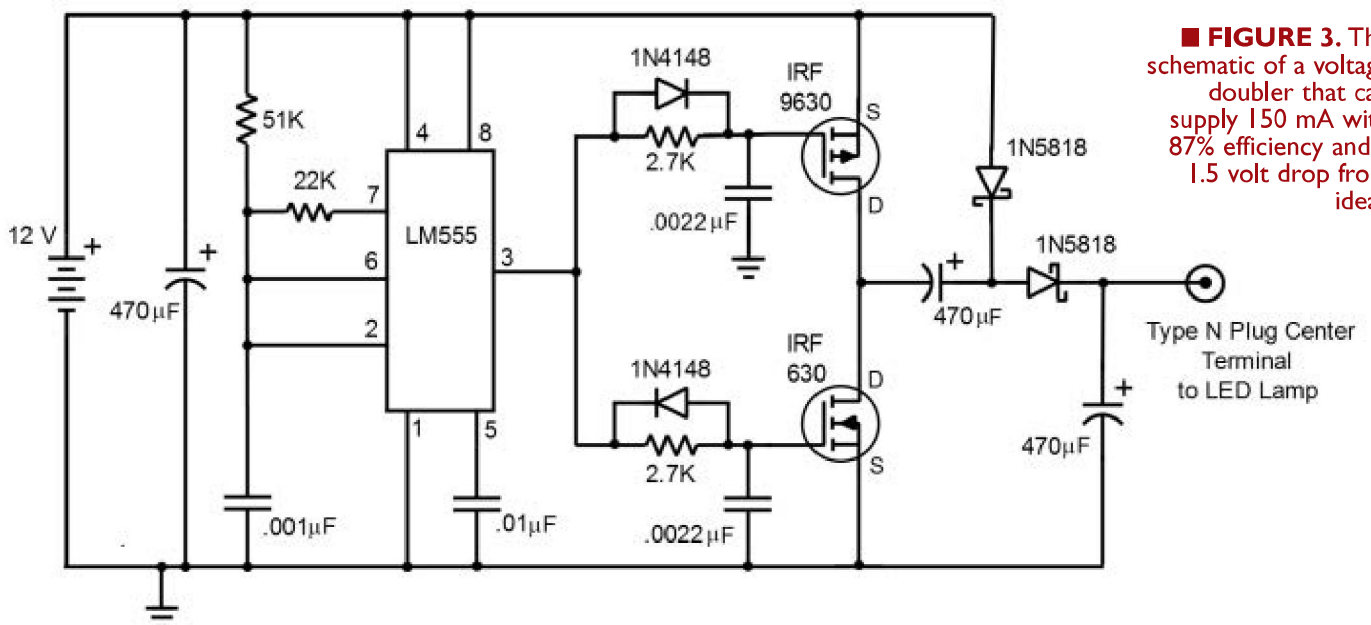




**FIGURE 2.** Block diagram of the battery power supply showing the three main components.

With the battery selected, the next step was converting the 12 volts to 20 volts. My first inclination was to go with an LM2577 step-up voltage converter, but I wanted to explore using a voltage doubler. I looked at many doubler designs and kept hitting the same problems: low current output and large voltage drop, which led to low efficiency. I couldn't find any circuit that would provide 150 mA at a minimum of 18 volts with a 10 volt

input. I developed the voltage doubler shown in **Figure 3** that just about meets the LED light voltage requirements. It uses an LM555 as a standard square wave generator that drives a standard push-pull power N-channel/P-channel MOSFET pair operating as a common source. I used a resistor/diode/capacitor network in series with the gates to prevent the two MOSFETs from being turned on simultaneously during the transition in the square wave

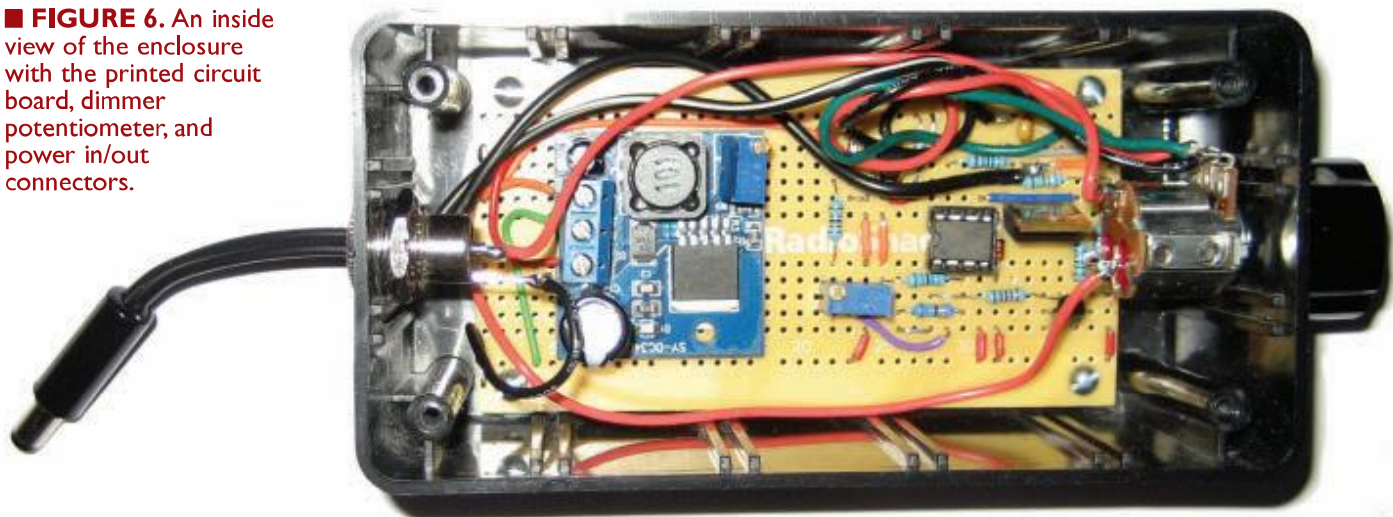


**FIGURE 3.** The schematic of a voltage doubler that can supply 150 mA with 87% efficiency and a 1.5 volt drop from ideal.





■ **FIGURE 6.** An inside view of the enclosure with the printed circuit board, dimmer potentiometer, and power in/out connectors.



about 65% at a 12 volt input, but is about 80% at a 10 volt input. Below 10 volts, the output drops below 18 volts. The reason for the early drop in efficiency is that the lamp — being current-source driven — uses a constant 2.6 watts at 18 volts. The extra voltage — 22.5–18 or 4.5 volts (68 watts) — is lost, primarily being dissipated in the current-source MOSFET.

The doubler was an interesting diversion but I ended up using an LM2577 based step-up boost converter ([Jameco.com](http://Jameco.com) part #2159349 DC-DC converter; \$7.95). This type of voltage converter has the advantage of working over a wide battery voltage range: -3.7 to 16 volts at better than 75% efficiency. (NOTE: You'll find voltage converters on eBay that can operate constant current/constant voltage. These all seem to be 'buck' converters which are used to drop the input voltage, for example, 12 volts in and five volts out.)

The current source and battery low voltage detector schematic is shown in **Figure 4**. At the far left is a voltage reference based on the LM185Z-1.2. This is an inexpensive band-gap voltage regulator diode that maintains a constant 1.235 volts. It provides the reference for both the current source and the battery low voltage detector. (A 5.1 volt zener diode could also be used, but it requires additional precision resistors and will have some loss in accuracy and stability.)

The current source consists of U1B/Q1 in a standard configuration. Variable resistor R2 is the dimmer control and at the maximum clockwise position, the full 1.235 volts is applied to the + input of U1B (assume for the moment that Q2 is in the off state, so R11 does nothing). The output of U1B drives the gate of Q1 which is working as a common drain (like an emitter follower). The voltage across R5 is fed back to the - input of U1B as negative feedback. This forces the voltage across R5 to be the same as the voltage at the + input of U1B or, in the case of maximum brightness, at 1.235 volts.

The current through R5 is therefore  $1.235/8.2 =$

150 mA, which must also be the drain current.

The 12 volt zener diode (any value from six volts to 15 volts is okay) from the Q1 gate to ground prevents the gate voltage from exceeding the gate's maximum rating of 20 volts. This could happen when the lamp load is not connected since the output of U1B would rise to near the 20 volt supply as the op-amp desperately tries to get the 150 mA flowing through a now open circuit. If the 20 volt supply happens to be set above about 22 volts, the gate would exceed 20 volts without the zener protection.

Most rechargeable batteries don't like to be heavily discharged, so I use the U1A op-amp circuit to monitor the battery voltage. U1A serves as a comparator with the 1.235 volt reference as one input and the R7-R8 divider providing the second input. If the battery voltage falls below the divider setting, the output of U1A will go high; Q2 will turn on, thereby grounding the Q2 end of R11. R11 together with R3 reduces the lamp current to about one third. This should be enough dimming to warn the user of the low battery condition. R11 could be changed to zero ohms for a complete turn-off, but I don't think it's a good idea to turn off the light during a power failure. R9 provides some hysteresis to the U1A comparator.

The safe low voltage trip point depends on the battery type. Li-ion batteries are somewhat delicate and a 12 volt battery should not discharge below about 8.5 volts. In fact, the DC-12680 has an internal circuit that disconnects the battery from the load at 8.5 volts. I set my trip point at 9.0 volts, so the lamp will continue working at reduced output for a while. Lead acid batteries are more forgiving but should not be discharged to below about 11 volts. Ni-Cad batteries should not be discharged to below 1.1 volts per cell. Check with your battery manufacturer for their recommended trip voltages.

Like many electronic experimenters, I use a universal solderless breadboard while designing. RadioShack has a matching printed circuit board (PCB) with a buss across the top and bottom, and 47 10-hole columns arranged



■ **FIGURE 7.** All the components assembled and operating.

five up and five down (RadioShack model 276-170). They also have a 5x2.5x2" project enclosure (model 270-1803) that is the correct width for the PCB but falls short on the length. **Figure 5** shows the assembly drawing for the lamp power supply. I cut the PCB just to the left of column 1 and just to the right of column 39 as shown. Also, the four holes have to be drilled. These are a bit oversized because

it's hard to get an accurate placement. The voltage converter is secured with a double-sided foam mounting square. The board is held in place in the enclosure with four 1/4 inch #4 screws.

**Figure 6** is a photo looking down into the enclosure. Note that I used a dimmer pot with a switch to completely disconnect the battery from the lamp power supply. Using the lamp on/off switch will not prevent some current drain from the circuitry; in particular, the voltage converter. In fact, I included the on/off switch for generality but I actually use the battery on/off switch since it also disconnects the battery's internal circuits. (NOTE: The battery on/off switch must be on when charging.)

**Figure 7** is the complete system: battery, power supply, and lamp. One end of the enclosure has the dimmer control and the other end has Type M panel jacks that connect to the power plug from the battery. This end also has a short pigtail lead with a Type N plug to mate with the lamp power input jack (Jameco part #2096771).

Assembly of the PCB is straightforward, except Q1 should be mounted off the board by about 1/4 inch. This will let you bend it down to avoid interference with the dimmer control (R2). The RadioShack potentiometer/switch that I used is

small and clears easily. I used small push terminals (Jameco part #34147) as connection points for all the wires leaving the PCB; you can also insert #22 wire into the PCB holes and solder them in directly.

Before you mount the voltage converter, trim any leads protruding on the solder side. Connect a DC power supply set to 12 volts to the converter input and use the trimmer on the converter to set the output to 20 volts. Stick the converter to the PCB with something like a Scotch mounting square and wire it in.

Set the low battery threshold trim pot (R8) fully counter-clockwise and set the DC power supply to 12 volts. Connect the lamp or substitute a 120 ohm 10 watt resistor for the lamp, and set R2 fully clockwise. Check the voltage across R5. It should be close to the LM185Z-1.2 voltage indicating that the current source is working properly.

To set the battery low voltage trip point, first set the DC power supply to your desired low voltage trip point and — while monitoring the voltage across R5 — turn R8 clockwise until you see a sharp drop in the voltage across R5. Raise the power supply voltage back to 12 volts and slowly reduce the voltage until you again get the sharp drop. If it's not at the desired trip point, make a small adjustment in R8 and repeat the previous up/down cycle until it is.

That's it. You're ready for final assembly in the enclosure. **NV**

## PARTS LIST

ITEM	DESCRIPTION
R1	68K, 1/4 watt 5%
R2	10K, Potentiometer with switch (RadioShack model 271-215)
R3	15K, 1/4 watt 5%
R4	10K, 1/4 watt 5%
R5	8.2Ω, 1/4 watt 1% film
R6	5.6K, 1/4 watt 5%
R7	8.2K, 1/4 watt 1% film
R8	5K, Trim potentiometer
R9	3.3MΩ, 1/4 watt 5%
R10	22K, 1/4 watt 5%
R11	6.8K, 1/4 watt 5%
C1	.1 μF, 50 volt disc ceramic
D1	LM185Z-1.2, 1.235 volt reference
D2	1N4742, 12 volt zener
U1	LM358N, Dual op-amp
Q1	IRF630, N-channel power MOSFET
Q2	2N3904, NPN transistor



# Raspberry Pi Based Remote Temperature Monitoring System

Figure 1. Temperature monitoring system concept

The Raspberry Pi has been a catalyst for the DIY community, allowing for easy access to high performance embedded computing. The open source embedded GNU/Linux software utilized by the Pi allows anyone to import high level code for almost any application, adding in the Pi's software accessible GPIO (General-Purpose Input/Output) ports, HDMI, Ethernet, USB interfaces, 700 MHz processing speed, and low cost. There isn't much left to be desired!

May 2013 **NUTS AND VOLTS** 35

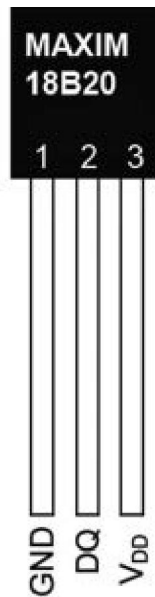
## Initial Setup of Thermal Monitoring System Hardware and Software

Our temperature monitoring system uses a Maxim DS18B20 thermal sensor. The DS18B20 digital thermometer provides nine-bit to 12-bit Celsius temperature measurements. It has an operating temperature range of -55°C to +125°C, and is accurate to  $\pm 0.5^\circ\text{C}$  from -10°C to +85°C (see the datasheet for more details).

The DS18B20 communicates over a 1-Wire bus. Each device has a unique 64-bit serial code. This allows multiple DS18B20s to function on the same 1-Wire bus, making it simple to use one microprocessor (or in our case, Raspberry Pi) to control many DS18B20s distributed over a large area. The DS18B20 is readily available and distributed by a number of vendors advertising in *Nuts & Volts*. If you happen to have an old version of the part (like a DS1820), that will work as well.

The GPIO header on the Pi has 26 pins; using software running on the Raspberry Pi, we can control and access these GPIO pins. The prototype schematic for the temperature monitoring system and its connection to the GPIO is shown in **Figure 3**. Red and green LEDs are used to indicate temperature status; red indicating an alert. In addition to this, a Fritzing drawing is included in **Figure 4**. (Smiley's Workshop has been covering the use of Fritzing extensively lately.)

You need to install the appropriate libraries for Python. All of the scripts here will be written using Python



**Figure 2.** The Maxim Integrated DS18B20 temperature sensor.

2.x, as the referenced libraries have not been revved to Python 3.x yet. The first library needed is the Python GPIO library. From the command line prompt, simply type:

```
pi@raspberrypi:~$ sudo apt-get
install python-rpi.gpio
```

The *sudo* part allows you to access the superuser status to run the apt package manager for Linux (if you omit *sudo*, you will get a permission denied response). After installation is complete, verify the installation by testing under *python*. Open the Python interpreter by typing *sudo python* at any command prompt. Note: You need to have superuser permissions to run the GPIO library in Python. You will see a new command

prompt (*>>>*) once the interpreter is active. Type *import RPi.GPIO as GPIO*. If the interpreter does not kick out any errors, we are good to go.

Modifying Python scripts (text files) is easily done using a simple text editor called *nano*. For the project to work, you should store all the files in the same folder.

The first script is the most basic way for the Pi to get our attention: illuminating an LED. Connect high efficiency LEDs as shown in **Figure 3**. GPIO pins on the Pi can be confusing, depending on your hardware version. Regardless of what Pi model you have, connect LED anodes to physical pins 11 and 13 using a series 470 ohm resistor for each LED; connect the cathodes to ground. For the Model A, these will be GPIO 17 and GPIO 21; for the Model B, these will be GPIO 17 and either GPIO 21 or GPIO 27 — please make sure your code reflects this or the green LED won't work.

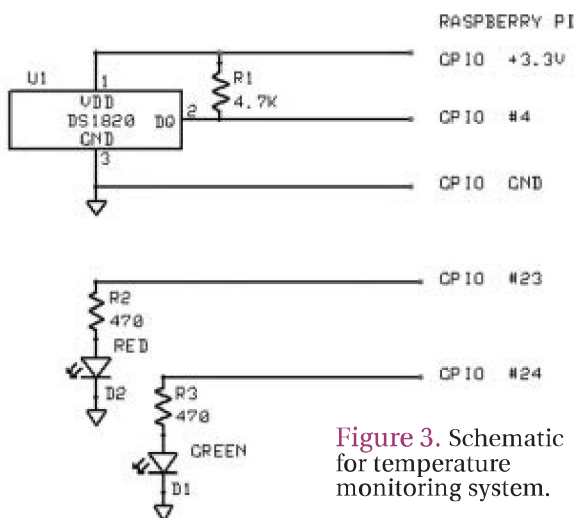
The actual physical pin connections are identical; the GPIO "pin" the software uses varies based on the hardware model as described above (you may end up blinking an Ethernet status light instead). Write up the following python script and make sure both your LEDs work.

Create a new file using *nano* by typing the following command: *nano led.py*. Once in the editor, enter the following code:

```
import RPi.GPIO as GPIO

RED = 17
GRN = 27

def set_LED(color, state):
    GPIO.setwarnings(False)
    GPIO.setmode(GPIO.BCM)
    GPIO.setup(GRN, GPIO.OUT)
    GPIO.setup(RED, GPIO.OUT)
```



**Figure 3.** Schematic for temperature monitoring system.



```

if color == 'red':
    if state == 'on':
        GPIO.output(RED, True)
        return 0

    elif state == 'off':
        GPIO.output(RED, False)
        return 0

    else:
        return 1

elif color == 'green':
    if state == 'on':
        GPIO.output(GRN, True)
        return 0

    elif state == 'off':
        GPIO.output(GRN, False)
        return 0

    else:
        return 1

else:
    return 1

```

Save the file by hitting CTRL^X and choosing Y. What we have done here is simply set up a function to call that will toggle each LED state. We will write a few more functions that will be called by our main temperature monitoring program. Writing each function as a separate script may be a bit more work now, but it will allow for easier modification later. The code imports the GPIO library we just installed, turns on the GPIO ports, and sets pins 27 and 17 to outputs. Then, the arguments are passed to a series of *if* statements to toggle the LEDs. To access the GPIO library, you need to have superuser privileges. Open the Python interpreter: *sudo python*. When the *>>>* prompt is shown, type: *>>> from led import \**. If you get any errors here, revisit the above code and see if you've made any mistakes. Also, double-check you've used the *sudo* prefix when you called Python.

Turn on the green LED by typing: *>>> set\_LED('green', 'on')*. Turn on the red LED by typing: *>>> set\_LED('red', 'on')*. You may be content to stay here and play with your LEDs for a while. Once you are ready, let's get our temperature sensor talking with Python.

First, we have a little detective work to do. Connect your DS18B20 as shown in **Figure 3** (make sure you get 3.3V and ground correct!). To determine the serial number for the part, we need to run some shell commands. Linux has a really intuitive way of handling hardware: Everything is a file! First, we need to kick-start the Linux kernel to include some additional capabilities to interface with our hardware. Enter the following commands in the console:

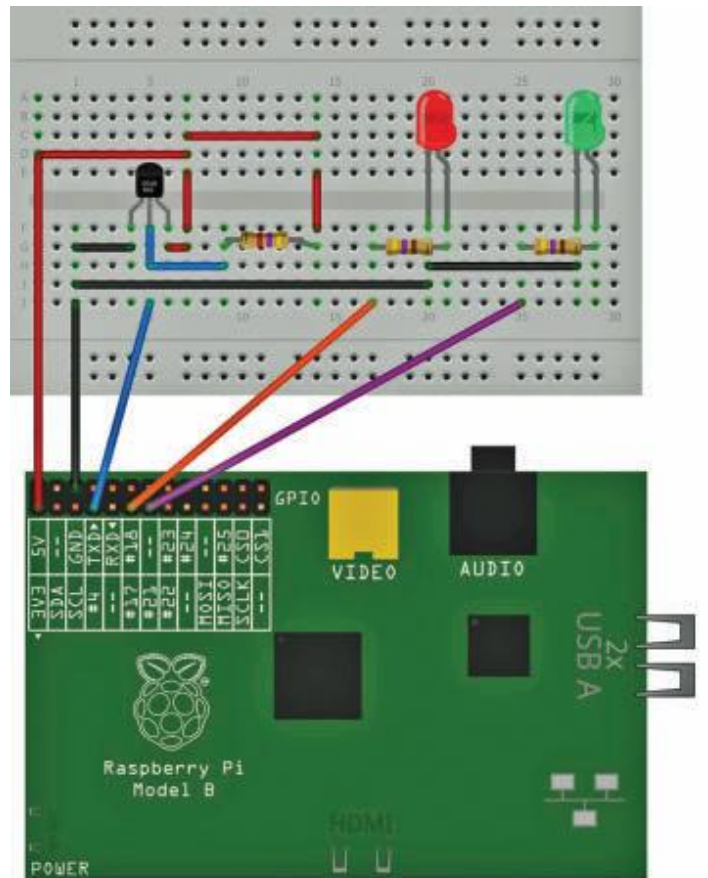
```

sudo modprobe w1-gpio
sudo modprobe w1-therm

```

Now, go into the bus directory:

```
cd /sys/bus/w1/devices
```



**Figure 4.** Prototype temperature monitoring system.

Made with Fritzing.org

Display the contents of this directory by typing *ls*. Several items like *w1*, *bus*, and *master* will appear. In addition to this, there is a *##-000xxxxxx-xxxxx* directory (**write this entire code down now; it is the serial number for your part**) which is how Linux interfaces with your temperature sensor. Go into that directory and run the *ls* command again:

```

pi@raspberrypi /sys/bus/w1/devices/10-0008004c05cc
$ ls
driver id name power subsystem uevent
w1_slave

```

We are primarily interested in the *w1\_slave* file. If you display the contents of this file using the *cat* command, it will force the sensor to do a reading – so, let's do it:

```

pi@raspberrypi /sys/bus/w1/devices/10-0008004c05cc
$ cat w1_slave
2e 00 4b fd ff ff 0f 10 6a: crc=6a YES
2e 00 4b fd ff ff 0f 10 6a t=22812

```

If you see a two line response with *crc= (some#) YES* on the first line, congratulations! You have successfully interfaced the DS18B20 with your Pi. The second line has

an element such as `t=22812`. This is the temperature in Celsius millidegrees. Feel free to play around here and rerun the command after warming up the sensor to prove to yourself it is actually reading the temperature. Just a reminder: Make sure you record the specific device ID information to get to this directory later. Check out the other files, too. If you add additional sensors, they will just show up as additional directories.

Go back to your project folder and create a new Python script called `get_temp.py`. Enter the following code:

```
import os

def init_temp():
    os.system('modprobe wl-gpio')
    os.system('modprobe wl-therm')

def temp_measure():
    device_dir = '/sys/bus/wl/devices/'
    device_ID = '10-0008004c05cc'
    device_file = device_dir + device_ID +
    '/wl_slave'

    try:
        f = open(device_file, 'r')
        temp_lines = f.readlines()
        f.close()

        error_check = temp_lines[0].find('YES')
        temp_pos = temp_lines[1].find('t=')

        if error_check == -1:
            return 1

        if temp_pos != -1:
            temp_celcius =
temp_lines[1][temp_pos+2:]
            temp_cel = float(temp_celcius) /
            1000
            print('Temperature = ', temp_cel, '
            deg C')
            return temp_cel

        else:
            return 1

    except:
        return 1
```

Let's try this out. Go back into Python and import our new script by typing:

```
from get_temp import *
```

To initialize the sensor, first run the `init_temp()` function. Then, call the `temp_measure()` function to get readings. If you want to record the temperature value to a variable, simply type `temp_variable = temp_measure()`. You will notice that the `temp_measure()` function takes about a second or two to complete. This is as fast as you will get data out of the DS18B20.

The code above should be intuitive. The main 'trick' we are using is the "os" library. This allows us to use Python to call shell commands (as we did above) to activate the sensor and read the `wl_slave` file. The

remaining code simply interprets the data. We are now free to do whatever we wish with the new temperature data. We have two very functional pieces of code that we can pull together into our next script. Open up a new file called `temp_monitor.py` (type `nano temp_monitor.py`); this will be the main script for running our temperature monitoring system. This script will call the libraries we have previously created; we will add to it as we go:

```
from get_temp import *
from led import *
import time

max_temp = 29
measure_delay = 10

temp_reading = 0

init_temp()

while True:
    temp_reading = temp_measure()

    if temp_reading > max_temp:
        set_LED('red', 'on')
        set_LED('green', 'off')

    else:
        set_LED('red', 'off')
        set_LED('green', 'on')

    time.sleep(measure_delay)
```

You don't have to go into the Python interpreter to run this file. Simply type:

```
sudo python temp_monitor.py
```

at the command line and it will start cranking away. Pinch the temperature sensor between your fingers and you should see the LEDs change state (change the `max_temp` value if you have too). Hit CTRL^C to exit.

That was easy! We now have the basis of a temperature monitoring system. However, our system isn't much use for actual remote monitoring yet. Fortunately, there is a lot more capability available with the Pi. Let's build some new functions that we can also call from our main program.

## Adding Email Notification

Giving the Pi the capability to email would be a great addition to our project. We will write the code to send an email with a file attachment. This attachment can be a Python-generated data log, a picture, or anything you desire. Just as before, we need to install the appropriate libraries for this to work; in this case, you need to install `smtplib` and `string`. Verify proper installation from the Python interpreter prompt as above.

```
def emailer(to_addr, subject, file_path):
```



```

import os
import smtplib
import string
from email import Encoders
from email.MIMEBase import MIMEBase
from email.MIMEMultipart import MIMEMultipart
from email.Utils import formatdate

email_from = "username@gmail.com"
password = "googlepassword"

msg = MIMEMultipart()
msg["From"] = email_from
msg["To"] = to_addr
msg["Subject"] = subject
msg["Date"] = formatdate(localtime=True)

part = MIMEBase('application', 'octet-stream')
part.set_payload( open(file_path,
"rb").read())
Encoders.encode_base64(part)
part.add_header('Content-Disposition',
'attachment; filename="%s"' %
os.path.basename(file_path))
msg.attach(part)

try:
    server = smtplib.SMTP("smtp.
gmail.com",587)
    server.ehlo()
    server.starttls()
    server.ehlo
    server.login(email_from,password)
    server.sendmail(email_from, to_addr,
msg.as_string())

    print("notification email sent to " +
to_addr)
    server.quit()
    return 0

except:
    print("Error sending email!")

```

Now, open up the Python interpreter and try this on for size. Import our new library (*from emailnotify import \**), then pass a command; all of the arguments are strings. Within moments, you should have an email in your mailbox. This new library is easily incorporated into our main function. Check the article link for *temp\_monitor.py* including the email function.

## Adding Simple Message System (SMS) Capability for Cell Phones

We can add additional capability to the system by taking advantage of a simple trick to send SMS messages. Depending on your carrier, you can send yourself or anyone an SMS using email. This is simply a “normal” email address — no special access is required. If it doesn’t work, check with your wireless provider. Refer to **Figure 5** and substitute the destination mobile phone number as indicated.

Hopefully, you are feeling somewhat satisfied with

AT&T	cellnumber@txt.att.net
Verizon	cellnumber@@vtext.com
T-Mobile	cellnumber@tmomail.net
Sprint PCS	cellnumber@messaging.sprintpcs.com
Virgin Mobile	cellnumber@vmobl.com
US Cellular	cellnumber@email.uscc.net
Nextel	cellnumber@messaging.nextel.com
Boost Mobile	cellnumber@myboostmobile.com
Alltel	cellnumber@message.alltel.com

Figure 5. Wireless providers.

your new powers. I really enjoyed getting to this point, but I’d also been tinkering with a few other libraries and realized there is a lot farther we can go with this project!

## Adding a Webcam Picture

For this next exercise, we will import another library and dig out an old USB webcam from our pile of junk. The installation of this library is much more involved. I recommend looking up “how to install simplecv” or go to **www.simplecv.org**. I found the basic instructions below. If these don’t work, go back to the website.

```

sudo apt-get install ipython python-opencv
python-scipy python-numpy python-pygame python-
setuptools python-pip

```

```

sudo pip install
https://github.com/ingenuitas/impleCV/zipball
/master

```

Note: This will take several hours to install on the Pi. Perform the same post-install check to make sure everything is operational:

```
from SimpleCV import Camera
```

NOTE: If this doesn’t work, try another webcam (there can be some hardware-specific issues here). If you are still unsuccessful, don’t worry — a fully supported Raspberry Pi camera should be released by May 2013. I’ve had good luck with both cameras I found: the Logitech V-UAR38 and Microsoft LifeCam VX-3000 (both circa 2006).

We will now build on our previous program. Say, for example, you really want to see what is happening at your house from a remote camera before hopping in the car and rushing home. Python can take a picture of any room/situation and attach it to an email.

Create a new file called *takepic.py*. Here is the code:

```

def take_pic(save_file):
    from SimpleCV import Camera

    try:
        myCamera = Camera()
        frame = myCamera.getImage()
        frame.save(save_file)
        print("picture capture successful!")
        return 0
    
```

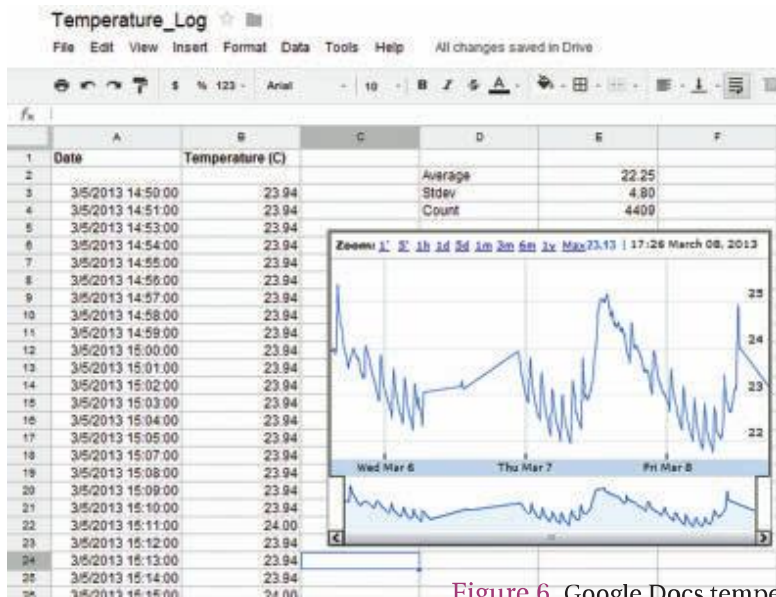


Figure 6. Google Docs temperature log.

```
except:
    print("picture capture FAILURE!")
    return 1
```

Get back into the Python interpreter and try out the new function. Pass any name.jpg you want to the function and it should spit out a viewable picture. From the

command line, you can use a program called "fbi" to view the file (`sudo apt-get install fbi` to install). Now, we can add a call to this function in our `temp_monitor.py` script and send a picture of an emergency over email.

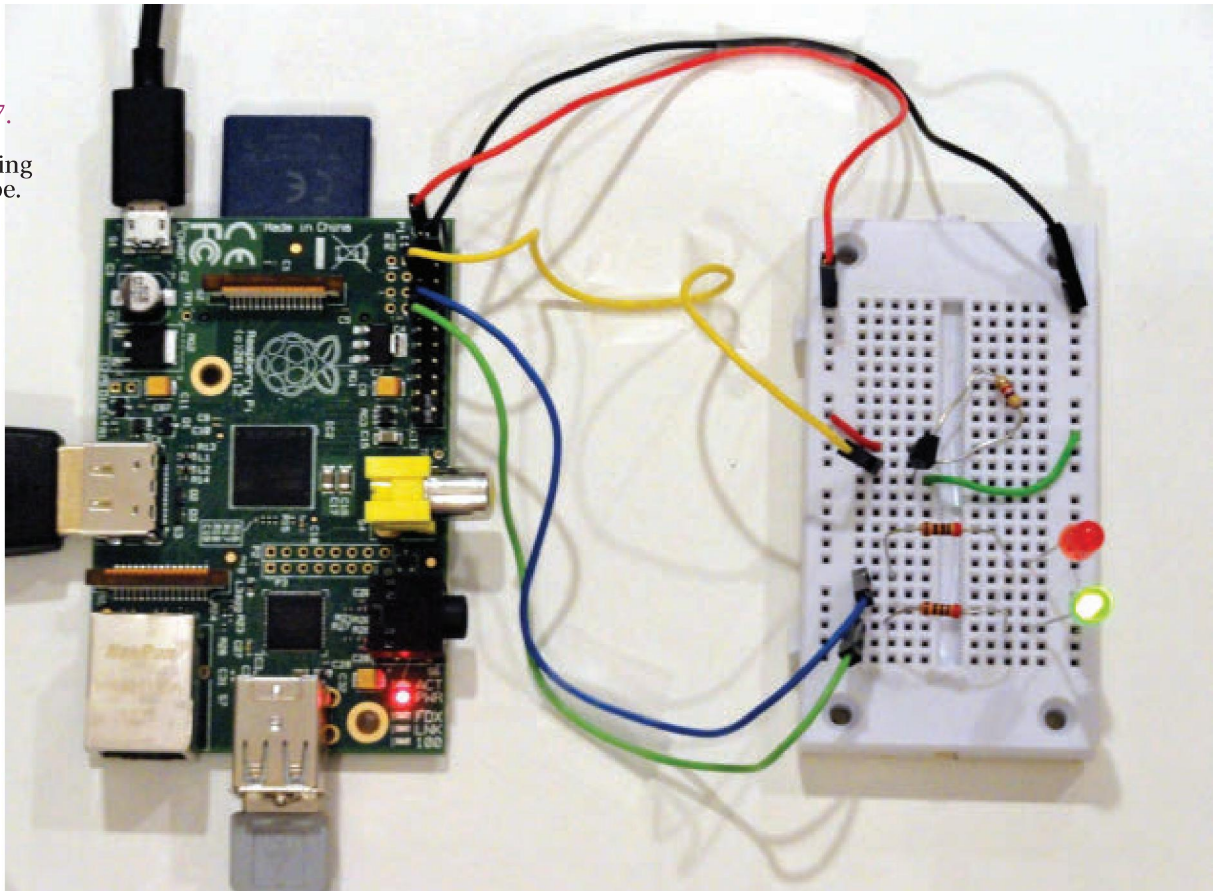
Wow! We are really getting a lot of information. Not only are we getting a red light emergency and an email with temperature information, but we are also getting a picture of what's happening at our house.

There is one last trick for this application. Wouldn't it be great if we could add useful data logging functionality? The answer is yes, and it is actually very easy using the `gsread` library. This library will give your application access to Google

Documents. You can log directly to a cloud-based spreadsheet. By this point, you should be comfortable installing and testing the `python-gspread` library on your own. Here is the code for a new library for our program (create a new file called `gdoc.py`):

```
def gdoc_update(data, row):
```

Figure 7. Remote Monitoring prototype.





```
import gspread
import datetime

uname = "username@gmail.com"
pword = "googlepassword"
logfile_sprdsht = "Temp_Log"

try:
    now = datetime.datetime.now()
    gspr = gspread.login(uname, pword)

    spreadsheet = gspr.open(logfile_sprdsht)
    worksheet = spreadsheet.sheet1
    worksheet.add_rows(1)
    worksheet.update_cell(row+1, 1,
        now.strftime("%Y-%m-%d %H:%M"))
    worksheet.update_cell(row+1, 2, data)

except:
    print("Error with gspread,
        continuing...")
```

Again, the fully implemented code for *temp\_monitor.py* is available at the article link. **Figure 6** is an example of a Google Documents spreadsheet populated by the code we have worked on here. The great thing about using Google Documents is that you can run all sorts of fancy calculations within the spreadsheet, and the *gspread* library allows you to pull in values from specific cells (think standard deviation, max,

min, average, etc.). This allows us to keep the Python code simple and let Google do some of the heavy lifting.

Our final code with all the features for the remote temperature capability (including detailed descriptive comments) is at the link, as well. A picture of the prototype is shown in **Figure 7**. Keep in mind that your username and password will be stored as plain text on your Pi. Consider opening a separate Google account for this application if it is an issue.

## What's Next?

Now, we have a cloud-logged dataset (we can check anytime and anywhere) and a control system that can notify us of an issue via text with an email attached picture of the situation. For the control freak in all of us, you can't help but appreciate the power of the Pi. After going through this exercise, you can easily see how the notification capabilities can also be applied to any number of imaginable projects.

I hope you enjoyed this quick overview. If there is enough interest, we will expand our control system locally and implement remote control over that system in future articles. **NV**



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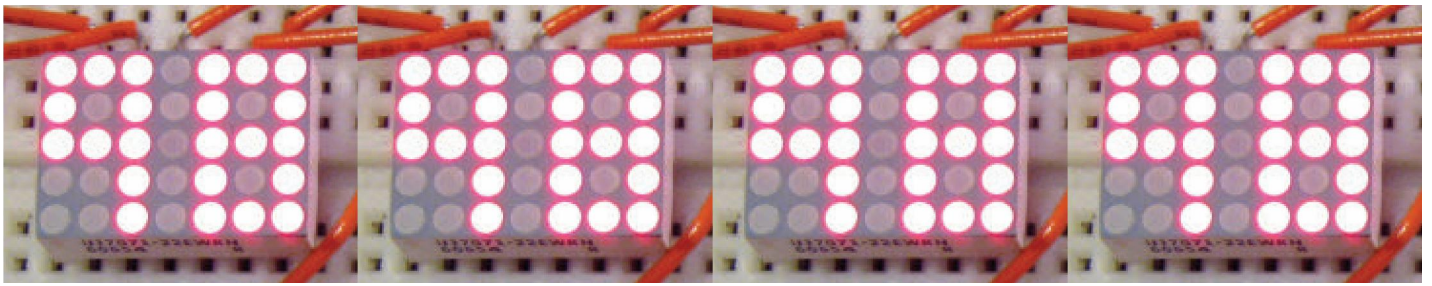
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# Getting Started with Matrix **LED** Displays

By Thomas Henry

For a bold and eye-catching output display in your next electronic masterpiece, consider exploiting a matrix LED device. As the name implies, this is an array of single LEDs arranged in rows and columns. When a particular intersection is specified, the LED element there turns on and shines away. Then, for example, groups of these can be selected to build up a pattern within a complete column. Finally, by rapidly sequencing a series of columns one after another (a process called multiplexing), a complete character is formed. Persistence of vision gives the illusion that all of the LEDs which make up the character are lit simultaneously. All in all, it's a pretty slick system and virtually open-ended. You'll be able to create just about any symbol or pattern you want, and can even animate things for some action-packed results.

**O**f course, you could always build your own matrix from discrete LEDs, but it's dispiriting to think of all the soldering that would entail. Fortunately, prefabricated packages arranged in rows and columns are available which completely eliminate that drudgery. Even better is that now these show up in surplus electronics stores, often for a pittance. The time has never been better to learn all about matrix LEDs, so let's dig in! Since we'll be utilizing a PIC, it is assumed the reader already has a basic understanding of how microcontrollers work.

## What's Inside?

For the purposes of this article, I'll home in on the LJ7071-22 five-by-seven LED matrix which is currently available for under three bucks from All Electronics.

Manufactured by Ledtech Electronics Corporation, it should be representative of most monochrome (one color) devices. You can download the datasheet for this part from [www.allelectronics.com](http://www.allelectronics.com). Since the display is organized as five columns by seven rows, it's no great surprise that this comes in a 12-pin package. The form factor is the usual DIP size, and you can plug it into a 14-pin socket if desired, leaving two spots empty. Let's look more closely at how things are organized within the part.

Refer to **Figure 1** which shows the arrangement. In this schematic view, a dot indicates an electrical connection. Otherwise, crossing lines are of no significance. Right away, we see that each of the five columns is a common cathode connection, while each of the seven rows gang common anodes. By grounding a column line and applying a positive voltage to a row line,



the LED at that intersection lights up. Don't do that quite yet, however, because we still need to add in a bit of support circuitry; if nothing else, some current-limiting resistors.

For reference, I've shown the pin numbers for the device I'm using. In general, it's probably more logical in what follows to call out the rows and columns. Just refer back to **Figure 1** when wiring things up. Of course, if you're using another unit, then the pinout could be different and you'll need to refer to the appropriate datasheet.

## The Basic Configuration

To turn this into a fully functional character display requires just a handful of common external components.

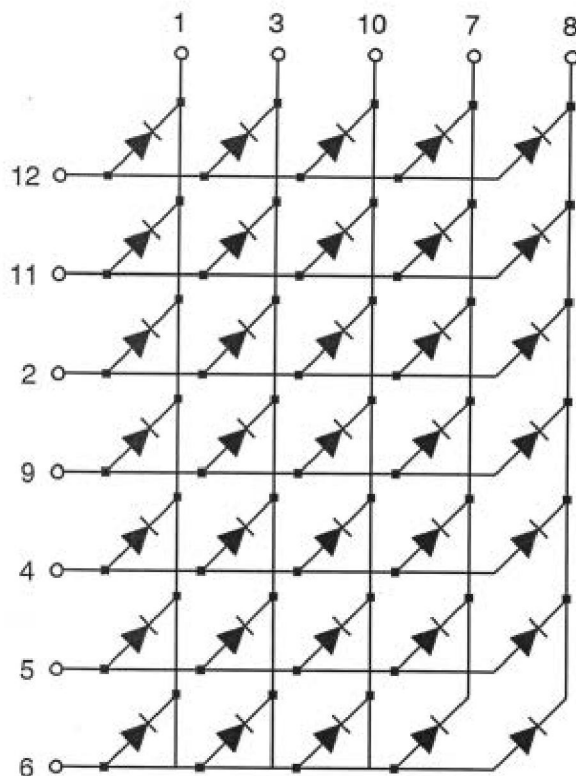
**Figure 2** shows a practical arrangement. Each of the rows is fed by a current-limiting resistor, and there are seven of these. The five columns, on the other hand, are controlled by transistors. Here, we use the ever-popular 2N2222. Think of these as voltage controlled switches. When a transistor is turned on, the common cathodes of the selected column are connected to ground and the chosen LEDs light up. We need a transistor, naturally, because more than one LED in a column could be lit. In other words, we might need to sink as much as 70 mA (assuming 10 mA per LED), and the 2N2222 can easily handle that. Note, however, we must make certain that only one column is selected at a time. More about that in a moment.

To aid your understanding, you can breadboard this affair as-is and test it by applying +5V to various row and column select inputs. For example, by applying +5V to resistors R1 and R8, the LED dot in the upper left-hand corner will light. By the way, did you notice that this arrangement responds to positive logic? The transistors have the happy side-effect of inverting the sense of things. That sure makes life simpler when trying to sort out bit codes for user-defined characters.

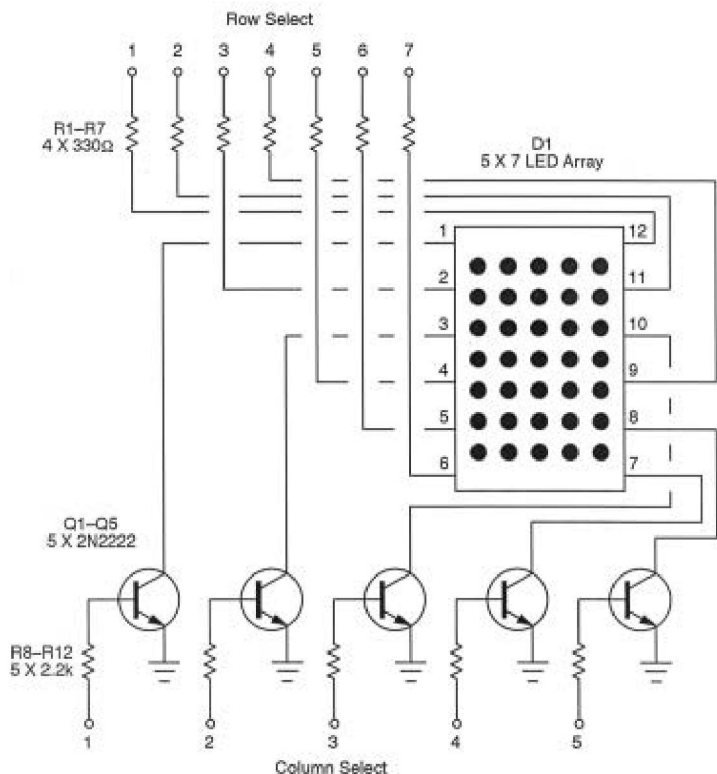
While it's instructive to see how this works with jumper wires choosing a row and column, it's pretty obvious we'll want to turn more extensive duties over to a microcontroller. The currents required by the matrix LED arrangement in **Figure 2** are well within the capabilities of most modern microcontrollers. Plan on 10 mA per row and less than 1 mA per column. Just make sure that only one column is chosen at a time. Otherwise, a row select line would be asked to supply more than the requisite 10 mA, putting the microcontroller at risk.

## Connect It to a Microcontroller

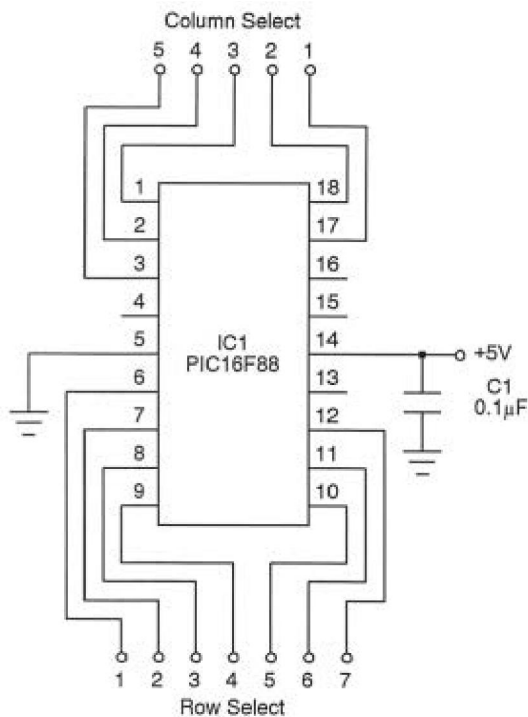
I like designing with PIC microcontrollers, but the logic of what we'll be doing is much the same for AVR's, Arduinos, and the like. **Figure 3** shows how the ubiquitous PIC16F88 can be pressed into service. With a couple restrictions, there are essentially two eight-bit ports at our disposal. Five lines of port A are used to



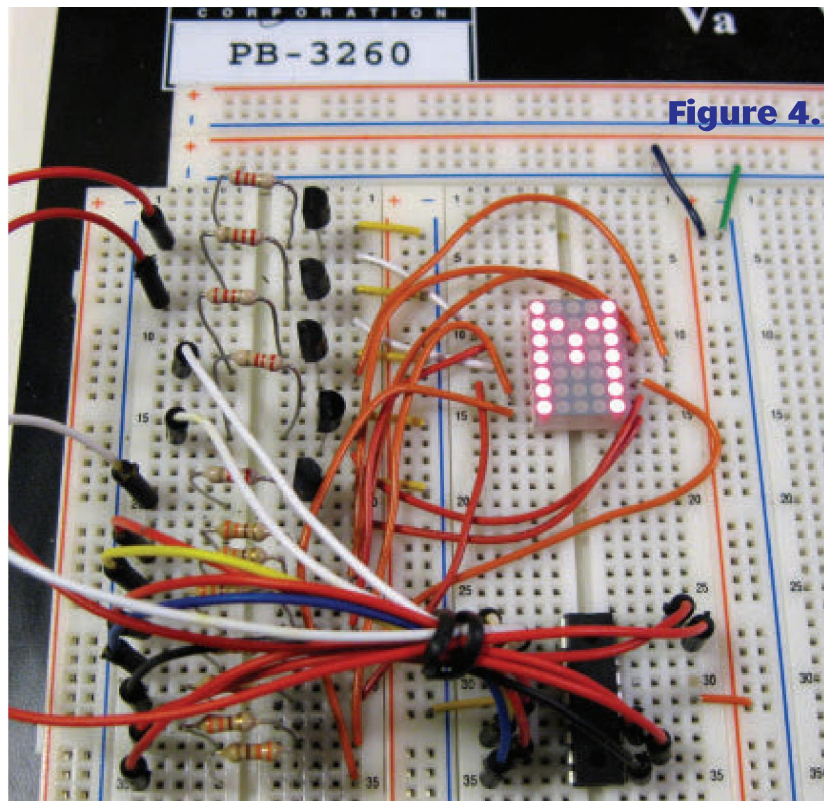
**Figure 1.** This is the LED arrangement and pinout of the Ledtech Electronics Corporation LJ7071-22 LED matrix display. Check your datasheet if using an alternative.



**Figure 2.** Drive this single-character display directly with the PIC circuit of Figure 3. Port A controls the columns, while port B controls the rows.



**Figure 3.** The PIC is labeled like this when the matrix LED is used vertically. Swap rows and columns when connected horizontally.



**Figure 4.**

## About the Firmware

The complete source code for the firmware (available at the article link) has been written in the free and open source Great Cow Basic language, which itself is available from [gcbasic.sourceforge.net](http://gcbasic.sourceforge.net). You might recall that I described this compiler in the November 2012 issue of *Nuts & Volts*, and it's put in appearances in several other articles since then. This really is an easy-to-use yet powerful package, and it's completely free — no strings attached! The three main source files and their purposes are:

- OneChar.GCB** — Display a single ASCII character
- TwoChar.GCB** — Display two ASCII characters
- Horizontal.GCB** — Display two digits horizontally on a single matrix LED

You'll also find two "include" files:

- Characters.GCB** — Bit codes for ASCII characters 32 through 127
- Digits.GCB** — Bit codes for 3 x 5 digits using negative logic

Bear in mind that Great Cow Basic files are really just ordinary text, so even if you're using an Arduino, for example, you'll be able to rip off the character bit codes and exploit them. That'll save you tons of time because designing a complete character set is usually fairly time-consuming.

Finally, the source code is heavily annotated. Thus, you'll be able to learn how the data is stored in tables and accessed; how Timer 0 is used to multiplex the columns; and so on. In short, perusing the code is a great educational endeavor. Of course, the comments also simplify the task of porting the code to other languages or processors should that be part of your agenda.

control the columns, while seven lines of port B handle the rows. This still leaves a few port pins left over for other uses. Just in case it isn't clear, we'll run things on the built-in 8 MHz clock, and also let power-on resets be handled internally.

So, just connect things up as in **Figures 2 and 3**, and away you go! **Figure 4** shows what the breadboarded result looks like.

We still have to figure out the software. Get the download package at the article link. In there, you will find the complete source code which drives our single character display. In particular, the firmware will put the unit through its paces, showing all of the standard ASCII characters including upper- and lower-case letters, digits, and punctuation. See the **sidebar** for more information on the programs.

## More Than One Character

Once you've figured out how to display a single character, it's pretty straightforward to extend this to longer messages. After all, each new character represents little more than five additional columns to be scanned. Theoretically, this ought to be easy, but after a moment's reflection it'll dawn on you that you may run out of port lines on the microcontroller. Here's one approach that keeps things manageable when displaying two-digit numbers.

**Figure 5** gives us the scoop. A CD4017 divide-by-ten counter is called upon to service the column select lines. Hey, that's pretty nice: Two characters of five columns each require 10 control lines — exactly what this CMOS chip has. Now, it's just a matter of stepping the counter along to multiplex the columns sequentially. All that's needed is a microcontroller port pin to clock the device, and a reset line to ensure the counting commences from the beginning.



So, to make a two-character display, repeat the circuitry of **Figure 2** for a total of 10 columns (10 transistors and 10 base resistors). Then, gang the row pins of the two matrix LEDs. For example, row resistor R1 goes to pin 12 of both display devices; R2 goes to pin 11 of both display devices; and so on. Conclude by connecting the 10 column rig to the circuitry of **Figure 5**.

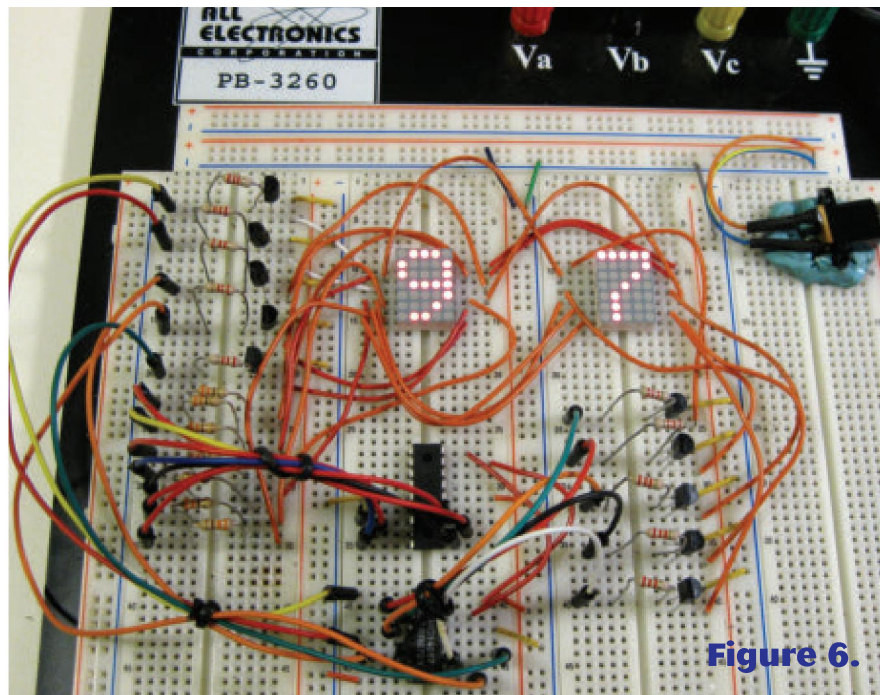
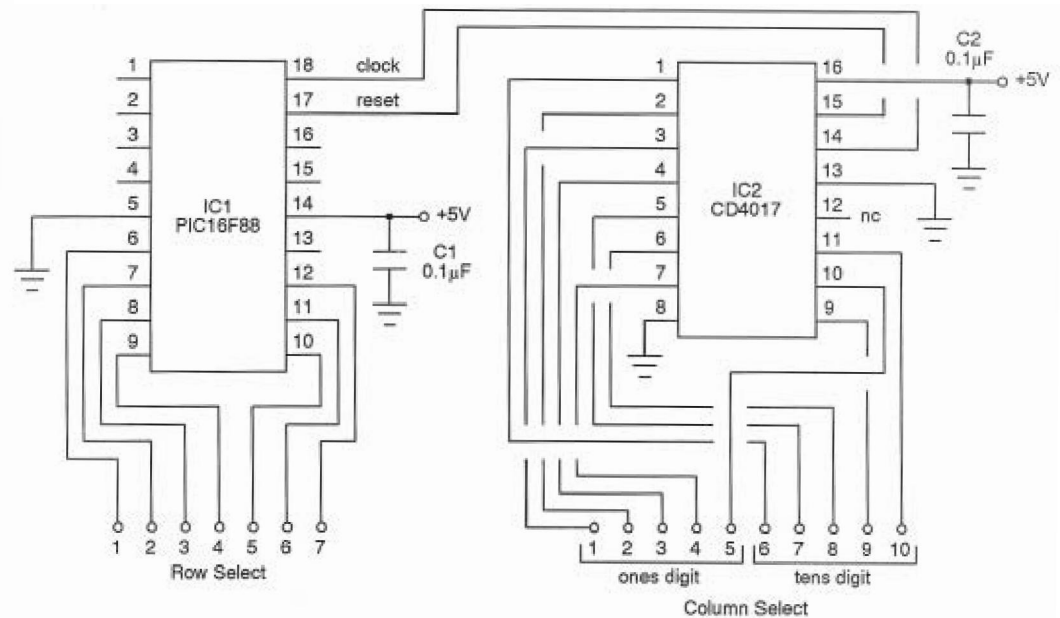
The sidebar explains what firmware to use for the two-character display. In this example, the unit will count from 00 to 99, and start over again. The coding really isn't much more involved and, as usual, lots of comments in the source code shed light on how it all works.

The photo in **Figure 6** shows what it ends up looking like. At first blush, you might think this is exceedingly elaborate until you realize there's actually very few parts there — just a lot of wires. A completed project on a printed circuit board would appear far less busy.

## A Two-Digit Horizontal Design

If all you need is the ability to show two digits (not alphabetic characters), then here's a neat trick. Rotate the matrix LED 90 degrees to yield a five-row, seven-column arrangement. Then, think of the display as being partitioned into a pair of three by five matrices separated by a blank column. See **Figure 7** for the details. Since we've flipped

**Figure 5.** For this two-digit display, duplicate Q1-Q5 and R8-R12 in Figure 2, and parallel row pins 12, 11, 2, 9, 4, 5, and 6, respectively, of the two display devices.



**Figure 6.**

## Help – I'm Out of Port Lines!

Matrix LEDs can gobble up microcontroller port lines in short order. For a simple display of one or two characters, the designs described in this article will hold you in good stead. If you really can't spare the pins or want to upgrade to multi-color rigs, here are some options to consider.

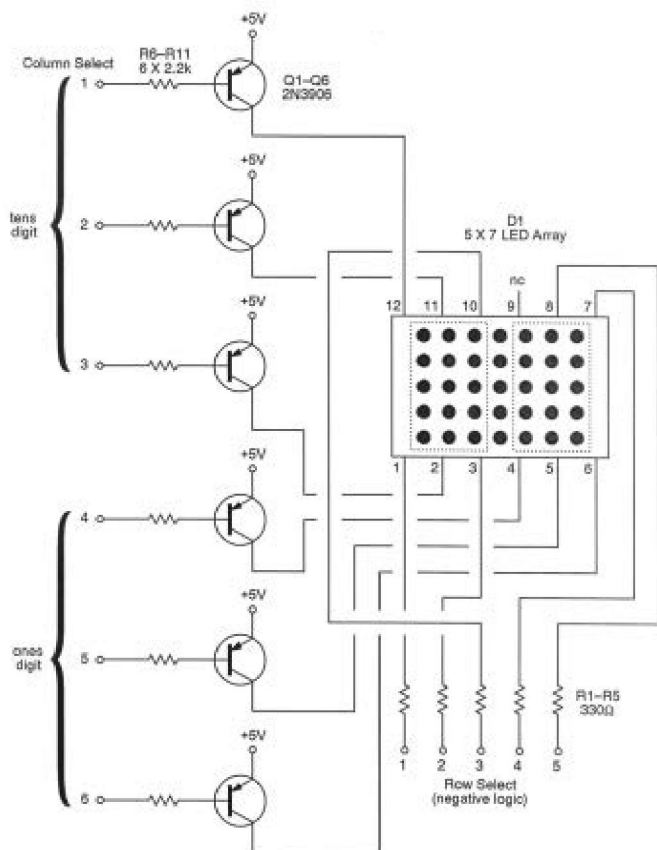
One possibility would be to exploit an external serial-in, parallel-out shift register chip like the common 74HC595. As the description suggests, the data which control rows or columns are pumped in serially, and the assembled bit pattern is applied to the LEDs in one fell swoop. Just be sure to watch the current handling capabilities of the chip. A more expensive but elegant approach for these displays would be a dedicated driver like the MAX7219 or MAX7221. These take care of all the matrix decoding requirements, and there's less worry about running out of

current to light the LEDs. More importantly, they can be interfaced by the SPI protocol which really frees up the microcontroller pins. However, they do run around \$10 a pop which may not fit your budget.

If your goal is simply to get a fancy display up and running as quickly as possible, check out the offerings of Adafruit Industries. You'll find them at [www.adafruit.com](http://www.adafruit.com). This outfit — which is quite popular among the Arduino crowd — offers an entire series of colorful matrix LED displays which are paired with an I<sup>2</sup>C interface. This is a two-line protocol which really cuts down on the microcontroller demands.

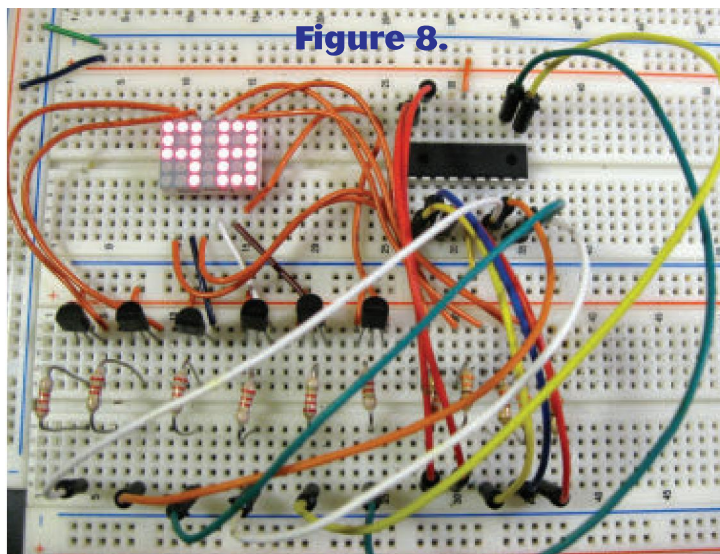
Best of all, I<sup>2</sup>C devices are addressable, so you can gang more than one display to create longer messages. Arduino fanatics are very familiar with both SPI and I<sup>2</sup>C communication, but not so widely known is that Great Cow Basic supports both as well, making these options available to PIC aficionados, too.





the orientation, the logic changes somewhat. In particular, the columns which become the common anodes must now be driven by PNP transistors and the newly christened row select lines are made active by grounding them. In short, negative logic is now the name of the game. That's the sort of thing microcontrollers are well suited for sorting out.

We'll still use the PIC circuitry of **Figure 3**, but simply exchange the "row" and "column" labels. Note, too, that pin



**Figure 7.** Drive this horizontal two-digit display with the PIC circuit of Figure 3, swapping the row and column labels. Now, port A controls the rows and port B controls the columns; pin 12 of the PIC is not needed.

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12 of the PIC has been freed up, since there are only six columns to drive now. It shouldn't take you more than several minutes to breadboard the revised horizontal arrangement. **Figure 8** shows what it looks like. Even though we've reduced the resolution, the digits are still

eminently readable. Not a bad way of easily attaining a two-digit display. Since negative logic is now in effect, a new set of character bit codes will be required. That's been taken care of in the software download for this article. Again, refer to the **sidebar** for the particulars.

## What's Next?

You should now have enough information at your fingertips to whip up some attractive matrix LED displays. Plus, you'll probably discover other uses and techniques as you play around with the three examples just described. Here are a few ideas to get you going.

Every time you tack on an additional matrix LED, you are — in effect — increasing the number of columns. This implies that each column is now being lit less frequently than before. The net effect is that the entire display may appear somewhat dimmer. One way to bring the brightness back up would be to decrease the value of the current-limiting resistors somewhat. This is actually fairly safe from the point of view of both the PIC and LEDs since the latter are only being pushed for the brief period they're actually on.

Another possibility is to play with the multiplexing frequency in software. In the three examples described here, the firmware updates the characters about 195 times per second, which is high enough to be free of flicker. Feel free to try other timing values and see what

you get. Custom characters are a snap. If you're using a PIC16F88 like I am, then there's oodles of room left over in program memory to hold additional character sets. Look over the source code files to see how the standard characters are stored, and then feel free to whip up some new ones.

As for animation, the sky is the limit. Why not see if you can implement a scrolling effect on your own; all it takes is some bit-twiddling. How about an exploding or dissolving character? You might even want to see if you can make the LED dots trace out a simple oscilloscope-like waveform. You get the idea; once the hardware is in place, you can have a heyday with the firmware and rapidly try out new and exotic ideas!

If you've mastered the techniques of this article and are anxious to do even more exotic things, then see the **sidebar** which describes additional advanced options. A quick perusal of catalogs and the Web suggests a lot is happening in the world of matrix LEDs. Now, you know the fundamentals and are prepared to take on these bigger challenges. **NV**

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# How to Make Professional Looking Control Panels and Enclosures

**Part 2**

By Gordon McComb

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This is the final installment on making inexpensive but high quality control panels and enclosures. Last time around, I showed how to use Inkscape — a free and open source vector graphics program to design the control panel artwork. The graphics are produced 1:1, meaning a 1/4" circle produced in Inkscape produces a 1/4" circle when printed. Elements of the control panel are produced using simple graphical shapes, such as lines, circles, squares, and text.

This time, we'll finish the discussion by detailing the ways you can print your completed graphics and transfer them to the metal, wood, plastic, or whatever control panel material you are using.



## Making Panels with an Inkjet Printer

Once your control panel has been designed in Inkscape (or other graphics program), you only need to print out the resulting image onto paper, plastic, vinyl, or other medium. When printing, be sure the image is reproduced at 100% with no scaling. Otherwise, the size of the control panel in the graphics program won't match the size of the printed result.

The choice of the printed medium is dependent largely on the printing process which (for most of us) is limited to inkjet and laser printers. In the printing world, the medium you print on is called the substrate. Certain substrates are best suited for certain types of printing.

The vast majority of consumer inkjet printers — such as the Epson model in **Figure 1** — use a water-based dye or pigment ink. Being water based, the ink must literally "soak" into the material, so this requires the substrate to be somewhat porous. Paper is the most common porous inkjet substrate. It's inexpensive, and comes in many finishes — smooth, rough, shiny, and others.

While there are some peel-and-stick paper labels available for inkjet printers, it's not difficult to apply the printed artwork substrate to the panel material using a spray or brush-on adhesive. For the latter, regular paper cement gives satisfactory results. When using a spray adhesive, find one for permanent application; many are designed for temporary use, and the adhesive loses its bond over time. For either spray or brush-on, make sure the adhesive doesn't discolor the paper or artwork. If it does, use a heavier paper or apply the adhesive in thinner coats.

A disadvantage to paper is that when cut or drilled, it tends to shred a little around the edges, like that shown in **Figure 2**. This is inconsequential if you're drilling holes for components that use washers or nuts to secure them. The hardware covers over the rough edges so no one sees them.

Shredding can become a problem with components (like LEDs) that are simply inserted into place. In such cases, you may wish to opt for LED mounting hardware which will conceal the shredding, or use a fine pair of scissors to trim off any dangling bits left over from the cutting or drilling.

Another disadvantage of using paper for panels is waterproofing. Unless you seal the finished art (I'll get to that in a bit), the paper remains porous to moisture, and can be readily damaged if wet. Paper can also show signs of wear and dirt — a consideration if the panel is expected to see more frequent use, especially outdoors.

To combat these problems, one alternative is water-permeable vinyl. It's thicker and more durable than paper, and is available as a peel-off sticker (see **Figure 3**). The trick is to find a printable vinyl for water-based inkjet printers. Most professional-grade printable vinyls are made for a completely different kind of ink that uses



**Figure 1.** This Epson Workforce 30 inkjet printer produces a rainbow of colors on a variety of paper and porous vinyl materials ("substrates").  
*Photo courtesy Seiko Epson Corp.*



**Figure 2.** Ragged holes are caused by drilling with dull bits or using the wrong drilling speed. Many imperfections can be hidden by the mounting hardware of the switches, pots, and other components in your control panel.



**Figure 3.** Peel-and-stick label stock makes applying the printed artwork a breeze.

## Tips and Tricks for Better Cuts and Holes

I've mentioned throughout this article that one of the problems of making control panels from printed substrates is that cutting and drilling can leave rough and frayed edges. What happens is that the cutting tool tears at the substrate, leaving little pieces behind.

As I said, you can hide much of these edges simply with the washers and other hardware of your control panel components. The mounting washer and nut for potentiometers, switches, and LED holders cover over the rough spots.

If your parts fit flush into the panel, you'll need to be extra careful how you cut and drill your artwork. Here are some tips that can literally help smooth the way:

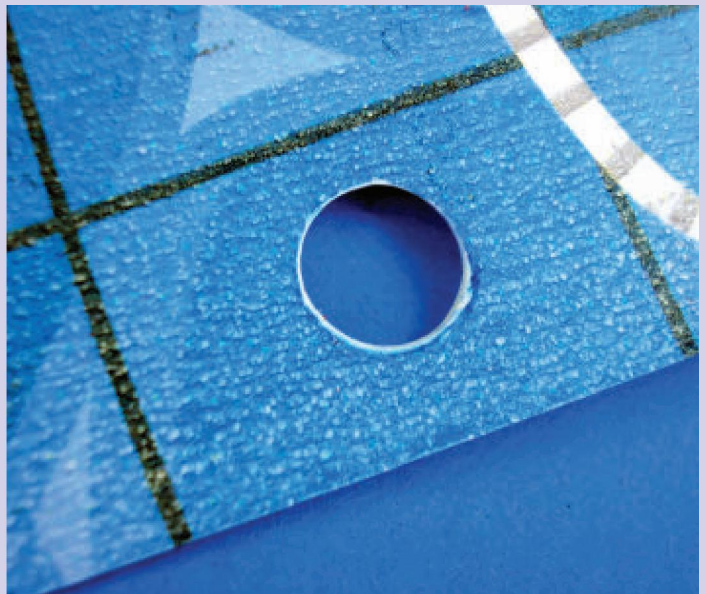
- Cut the printed substrate to size first using a paper cutter, making it slightly larger than the control panel itself. Trim any excess around the edges with a sharp hobby knife (careful — these knives are sharp!!).
- Apply the substrate to the control panel before drilling any holes.
- Use only sharp cutting tools and drill bits. Fraying is made worse with dull tools.
- When drilling, back the control panel with a piece of scrap wood. This will help prevent splintering the panel, or producing ragged and uneven holes.
- Try using drill bits with brad points (**Figure A**). These bits are commonly used with plastics to avoid chipping. If such bits are not available to you, drill a small pilot hole first, then enlarge the hole to the correct diameter with successively bigger bits.
- Depending on the control panel material, try drilling at a higher speed. For most plastic and wood, you can drill at medium or high speed and still cut through the material. For aluminum, you should keep the drilling speed low.
- When using paper, vinyl, and thin polyester labels, some fraying is inevitable. Carefully trim off

any excess with a hobby knife.

- Try using a sheet of 10 mil synthetic paper for the control art. These tend to hold up better when drilled, and leave little or no frayed edges as long as only sharp tools are used. An example hole in synthetic paper is shown in **Figure B**. Synthetic paper requires a laser printer or copier.



**Figure A.** Brad point bits helps to reduce the fraying that occur when drilling into paper and other thin substrates. Be sure your tools are sharp.



**Figure B.** The thicker (10 mil or more) synthetic paper, actually made of polyester sheet, is less prone to shredding when drilled.

solvent. This stuff is of no use to you. If you try to use a water-based printer on these vinyls, the ink will just puddle on the surface and make a mess. A few sources for this type of printable vinyl are listed on **Robotoid.com**.

Another type of printing substrate you might consider is printable fabric. This is a possibility if your panel is meant to be flexible, like something you attach to your t-shirt and wear. There are two general methods for printing on fabric:

*Direct printing* passes the fabric through the printer. For this to work, the fabric needs to be thin enough to go through the printer, and rigid enough that it doesn't get snagged or folded up while inside.

*Heat transfer* prints on a special sheet that's fed through the printer. The image is then literally transferred onto the fabric of your choice using heat and pressure.

Of the two methods, heat transfer is generally easier and less prone to problems. You can get printable heat transfer sheets at most craft and fabric yardage stores such as Joann's and Michael's. Opt for the transfer sheets for light colored garments. Read the instructions for suitable fabrics you can transfer to. Most sheets will adhere to 100% cotton, cotton/polyester blends, and certain 100% polyester fabrics that don't have a sheen. Avoid the use of super-stretchy fabrics, nylon, and other synthetics.

To transfer the printed image to the fabric, you'll need a clothes iron, though a heat press is better. You might be able to borrow a heat press if you have a friend that does rhinestone art or makes custom t-shirts.

Once printed or transferred, you'll need to cut out the holes and other openings in the fabric for any parts attached to the panel. You can use scissors or a hobby



knife. For fabrics that are prone to fraying when cut, dab on a little Dritz Fray Check (available at craft and yardage stores) to minimize any runs.

## Making Panels With a Laser Printer

The other popular option for making good looking homebrew control panels is the laser printer. Although a monochrome (black only) printer will work, you'll want a color printer to make more vibrant panel designs. Even if you don't have your own color laser printer, you can take your artwork to a nearby business copy center and have it done there. An example of a consumer-level color laser printer is shown in **Figure 4**. Like inkjet, the most common substrate for laser printing is paper. As with inkjet, paper panels may degrade more quickly if they are subjected to moisture, liquid, dirt, and regular use.

A better substrate is polyester labels with a permanent adhesive. This stock is available from many office supply stores, or online from sources like Labels By The Sheet (see the **Sources** box). The polyester is thin but more rugged than plain paper. It's difficult to tear, naturally water resistant and, if dirtied, can be cleaned by wiping it with a damp cloth. Opt for the gloss or matte white labels. This gives your control panels an opaque white background for whatever colors you want to print.

A step up from polyester labels is so-called *synthetic paper* — a term used for any of a variety of polyester-based printing media designed for use in high-end laser printers and copiers. Xerox, Neekosa, and others make a variety of synthetic papers with different thicknesses and surface finishes. It's sold as an alternative to printing on paper and laminating with a plastic protective cover. Thicknesses range from a relatively thin 6 mil (six thousandths of an inch) to a robust 12 or 13 mil. I recommend going with an 8-11 mil paper for control panels. While you can purchase packages of synthetic paper from the online stores for Staples and even Walmart, unless you're doing lots of panels you may find it overall less expensive to simply take your art to a local business copy center. Most of the better ones will have a variety of synthetic papers to choose from. Bring in your art on a USB thumb drive in TIF or PNG format. The smallest page they'll do is 8-1/2" by 11". So, if your panel is small, try to gang it up with others to avoid waste, or make extras on the same sheet just in case.

Depending on the type and thickness of the digital paper, you may find this stuff fares much better when cut and drilled. I found that a brad point drill bit — like that for making holes in acrylic plastic — left little or no ragged edges. Any rough edges left were easily removed with a small hobby knife.

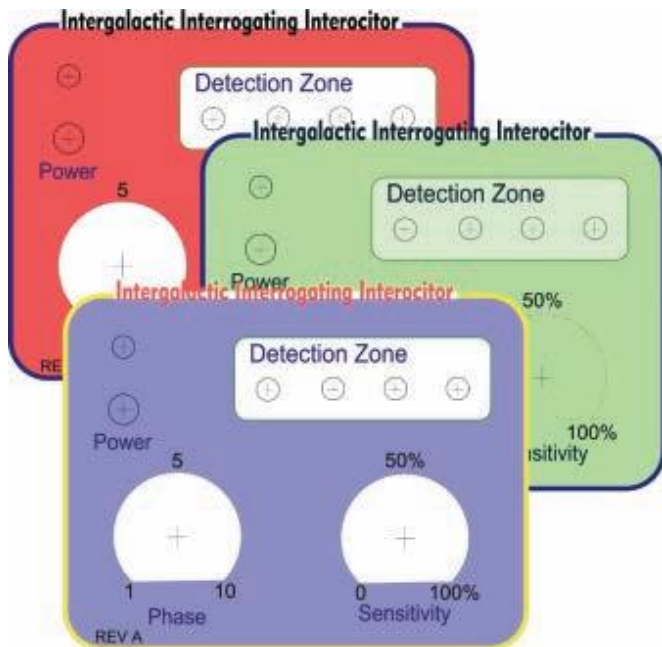


**Figure 4.** Color laser printers can be used with paper, polyester labels, and so-called digital paper to produce long-lasting control panels. Photo courtesy Oki Data Americas, Inc.

## Protective Coatings for Waterproofing and Wear

When using paper and vinyl substrates, you'll probably want to protect the surface against spoilage from moisture and handling. (Digital paper substrates are naturally waterproof, and can be cleaned using mild detergent and water.) The two most common ways of protecting the artwork are clearcoat spray and lamination.

- After printing, apply a coat or two of clearcoat spray, such as Krylon Acrylic Crystal Clear. Select a spray with the finish you want; choices are matte, satin, or gloss. I prefer matte or satin, but the resulting texture may not be as smooth as you'd like. Let the coat dry completely before using the panel.
- Apply a thin sheet of protective plastic using a pressure- or heat-sensitive laminator. The plastic should be applied after printing, but before cutting and drilling. One drawback to pressure applied lamination: Tiny air bubbles can get trapped underneath, marring an otherwise beautiful control panel. Some types of lamination plastic have tiny holes in it to let the air out. If yours lacks this feature, you can reduce or eliminate the bubbles by piercing them with a sharp hobby knife, then pressing down to get out all the remaining air.



**Figure 5.** Feel free to use bold color to enhance the appearance of your control panels. Text should be in a contrasting or complimentary color to the background.

## Ideas for Improving Your Panels

Here are some tips for making your panels even better:

If you have — or have access to — a laser CNC machine, you can use it to cut and drill your control panels. After printing, apply the paper, label, or other substrate to the panel, then cut the panel on the machine.

The material that forms the backing of the control panel must be suitable for laser cutting; acrylic, thin wood, and polycarbonate are three popular materials. You'll get the best results with acrylic, which burns through with little flaming or rough edges.

Rigid PVC is not recommended as this plastic gives off toxic fumes that pose a health risk to you, and can damage the CNC machine. When cutting through paper, the edges may appear scorched.

Don't be afraid to experiment with color. Try variations in your designs to see which works best. Rather than a drab white or gray background, consider going with a dark blue or vibrant red. Use contrasting colors for text. **Figure 5** shows a trio of examples.

Enhance the look of your projects by using special fonts for the text, but don't go overboard. Use a decorative font for the name of your project, then use a standard non-serif font like Arial or Helvetica for any descriptive text. Judicious use of color and effects can help the text stand out.

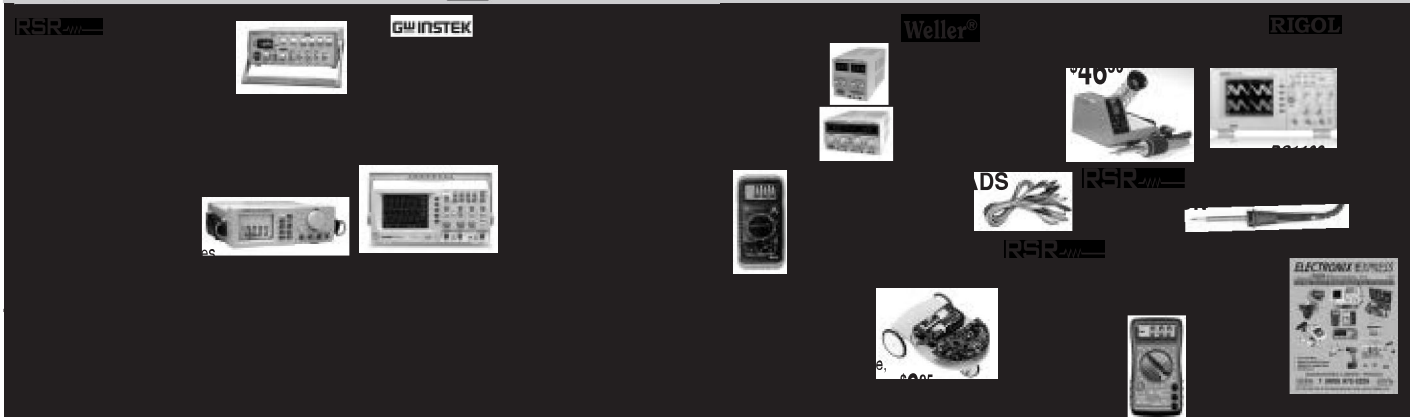
For example, using Inkscape or most any other graphics program, you can add a contrasting drop shadow behind the text to help make it more visible.

Finally, projects for kids can be embellished by using their favorite artwork and characters. Add a background of cars, trees, surf, pirates, or anything else that catches their fancy.

Doing a Halloween-themed project? Import an image of ghosts and place on a black background. Add slimy green text for a finishing touch. **NV**

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## Printing with Sublimation

Water-based inkjet and laser printing are the two most common methods for creating colorful artwork for control panels. Both involve printing directly to a substrate or, in the case of fabric, printing first to a transfer sheet, then using heat to apply the sheet to a piece of cloth.

There is an additional method of printing on substrates — one that involves heat transfers using specialty dye dispersant inks. It's called sublimation, and it produces rich and vibrant color where the printing is a physical part of the panel material. The printing is fade- and water-resistant.

In dye sublimation, an inkjet (or less commonly laser) printer produces the artwork on a sheet of thin transfer paper. The colors are made using a dye that is specially formulated to absorb into many kinds of synthetic materials — especially polyester. The actual dye transfer occurs under very high heat — on the order of 375 to 400 degrees — and under pressure. Once transferred, the dyes are locked into the material and cannot be washed out.

**Figure C** shows the top cover of an Arduino project made using dye sublimation. The cover material itself is made of a thin hardboard, overcoated with a white polyester resin. After cutting the hardboard to shape, the rainbow image was first printed onto paper, then the paper was heat-pressed to the coated hardboard.

Rigid substrates for sublimation include the aforementioned hardboard, plug aluminum sheet, and plastic reinforced fiberglass. In all three, there is no separate paper, vinyl, or polyester film that's first printed to, and nothing is glued afterward to the substrate. Rather, the substrate itself is coated to directly absorb the specialty dyes.



**Figure C.** Dye sublimation impresses the color directly into the metal, plastic, or wood control panel material. It requires specialty dye inks and a very hot heat press.

service bureaus that will sublimate printed artwork onto the substrates of your choice. See the **Sources** box for more info.

### Sources

**Conde**  
Sublimation and heat transfer supplies, specialty printing substrates.  
[www.conde.com](http://www.conde.com)

**Labels By The Sheet**  
Peel-and-stick labels for

laser and inkjet printers, sold by the sheet.  
[www.labelsbythesheet.com](http://www.labelsbythesheet.com)

**Robotoid**  
Resources for control panel design and construction, resources for sublimation, and more.  
[www.robotoid.com/panels](http://www.robotoid.com/panels)



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## CONTROLLING HOMEBREWED DEVICES WITH A PS DUALSHOCK 3

There are some things in life that must be done. This project is one of them. How can any red-blooded geek or nerd resist the siren song emanating from the multitude of buttons and joysticks that reside on the island of PlayStation DualShock 3? This month, we will begin an odyssey that will take us to the villages, towns, and cities of a province called USB, which resides in the land of PlayStation. We will travel on a Microchip PIC32MX fueled by the Microchip Application Libraries' free USB stack. Along the way, funds for our travels will be provided by Ellisys and the Microchip X series of C compilers and IDEs. By the time we arrive at our destination, you will be an experienced USB traveler. In addition, you will have also mastered the USB ways of the PlayStation DualShock 3 controller.

### THE PLAYSTATION DUALSHOCK 3

There isn't much I can tell you about the physical PlayStation DualShock 3 that you don't already know. Besides, we humans are already programmed to push buttons and wiggle joysticks. In that we want to manipulate the PlayStation DualShock 3 with USB bits of our choosing, we'll take a look at what is going on inside of the DualShock 3.

The best way to get the skinny on the DualShock 3 USB speak is to smell the PlayStation 3's cooking. Our DualShock 3 USB sniffer is the Ellisys USB Explorer 200 you see standing on its four rubber feet in

**Photo 1.** I used my laptop and a free program called MotioninJoy to awaken the DualShock 3. The USB Explorer 200 captures the DualShock 3 USB data stream by sitting between the MotioninJoy application and the PS3's USB interface. A typical Explorer 200 USB session capture can be seen in **Screenshot 1.**

To get a good idea about what we need to code to connect with the DualShock 3, we'll use the Explorer 200 to sniff out the PS3's USB descriptors. The Microchip USB stack automatically retrieves the PS3 descriptors at enumeration time.

A quick look at **Screenshot 2** tells us that the PS3 is bus powered and would like to use the maximum



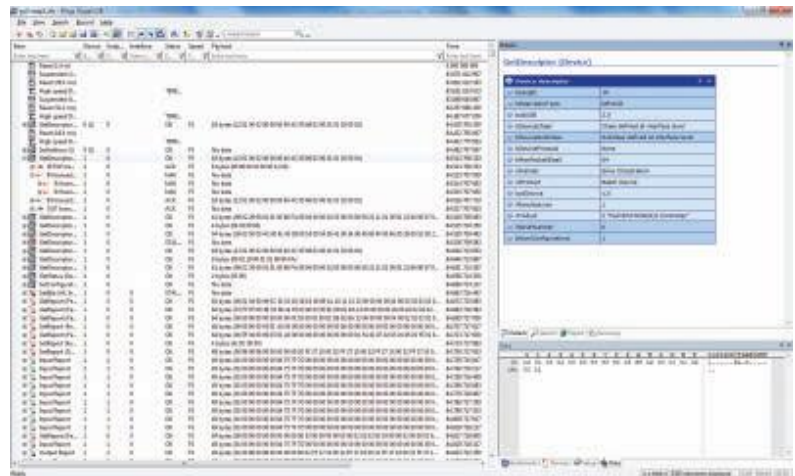
■ **PHOTO 1.** Other than capturing every little nuance of a USB data stream, I am able to use the Ellisys USB Explorer to record those data streams for further analysis. All you have to do is load and run a copy of the free Ellisys Visual USB application to view my recorded USB data stream captures with your PC.



available USB bus current of 500 mA. The **Screenshot 2** data also tells us that the PS3 has a single interface (interface 0) that supports two endpoints. Physically, the DualShock 3 acts as a human interface to a PS3 console. So, if logic prevails, the DualShock should logically fall into the USB HID (Human Interface Device) class. According to its interface descriptor, it is indeed part of the HID class of USB devices. The presence of a HID descriptor is also a dead giveaway. As for the pair of endpoints, the endpoint descriptors you see in **Screenshot 3** tell us that they are both interrupt endpoints that can accept a maximum packet size of 64 bytes. Both endpoints operate within 1 ms frames. The address of the OUT endpoint is 2, while the IN endpoint's address is 1.

Since we're using the Microchip USB stack and we will be running our PIC32MX795F512L as a USB host, we will want to utilize the Microchip USB OTG configuration tool. To effectively use the OTG tool, we will need to know our DualShock's PID (Product ID) and VID (Vendor ID) assignments.

There are a number of ways to obtain the PID and VID. We can do it the hard way or we can do it the easy way. If you're a Design Cycle regular, you already know which method I will use. I removed the DualShock's USB cable from the Explorer 200 and plugged it directly into my laptop. I kicked off the Kadtronix USB HID demo application and in the blink of an eye, the DualShock 3's PID and VID appeared in base 10 format. My Diligent



■ **SCREENSHOT 1.** This is a very busy shot. However, every bit of data on this screen is important to us. To find the PlayStation DualShock 3 holy grail, we need to know exactly what is passing between the MotioninJoy application and the PlayStation DualShock 3.

Interface descriptor	
bLength	Valid
bDescriptorType	INTERFACE
bInterfaceNumber	0
bAlternateSetting	0
bNumEndpoints	2
bInterfaceClass	Human Interface Device [Find out more online]
bInterfaceSubClass	Unknown (0x00)
bInterfaceProtocol	None
iInterface	0
HID descriptor	
bCountryCode	Not Supported
bNumDescriptors	1
bDescriptorType[0]	REPORT
wDescriptorLength[0]	148 bytes
Endpoint descriptor	
bLength	Valid
bDescriptorType	ENDPOINT
bEndpointAddress	2 OUT
bmAttributes, TransferType	Interrupt
bmAttributes, Reserved	Zero
wMaxPacketSize	64 bytes
bInterval	1 frame (1000 us)
Endpoint descriptor	
bLength	Valid
bDescriptorType	ENDPOINT
bEndpointAddress	1 IN
bmAttributes, TransferType	Interrupt
bmAttributes, Reserved	Zero
wMaxPacketSize	64 bytes
bInterval	1 frame (1000 us)

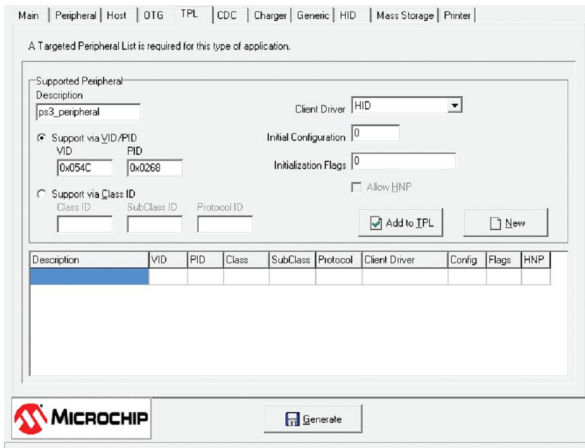
■ **SCREENSHOT 3.** Our embedded USB host will only talk to a PlayStation DualShock 3 controller. So, we can use the DualShock 3 endpoint descriptors we sniff with the Ellisys USB Explorer 200 to nail down the IN and OUT endpoint addresses.

GetDescriptor (Configuration)	
Configuration descriptor	
bLength	Valid
bDescriptorType	CONFIGURATION
wTotalLength	41 bytes
bNumInterface	1
bConfigurationValue	1
iConfiguration	0
bmAttributes, Reserved	Zero
bmAttributes, RemoteWakeUp	Not supported
bmAttributes, SelfPowered	No, Bus Powered
bmAttributes, Reserve7	One
bMaxPower	500 mA
Interface descriptor	
bLength	Valid
bDescriptorType	INTERFACE
bInterfaceNumber	0
bAlternateSetting	0
bNumEndpoints	2
bInterfaceClass	Human Interface Device [Find out more online]
bInterfaceSubClass	Unknown (0x00)
bInterfaceProtocol	None
iInterface	0
HID descriptor	
bCountryCode	Not Supported
bNumDescriptors	1
bDescriptorType[0]	REPORT
wDescriptorLength[0]	148 bytes
Endpoint descriptor	
bEndpointAddress	2 OUT
bmAttributes, TransferType	Interrupt
wMaxPacketSize	64 bytes

■ **SCREENSHOT 2.** USB descriptors aren't as complicated as one would expect. If you take the computer science out of the equation, descriptors can be very helpful tools in determining how a USB device works.

Choose an available device below by clicking its device name. Then, click "Open" to connect to the device. Click "Refresh" to update the device list.				
Device Name	Manufacturer	Vendor ID	Product ID	Serial Number
chpKIT Programmer	Digilent	1240	30032	D4E70601
PLAYSTATION	Sony	1396	616	
<input type="button" value="Open"/> <input type="button" value="Refresh"/> <input type="button" value="Cancel"/>				

■ **SCREENSHOT 4.** Automobile mechanics have their "special" tools, and we have ours.



■ **SCREENSHOT 5.** The Microchip USB OTG Configuration Tool generates our `usb_config.c` and `usb_config.h` files. Both files contain information that is essential to proper operation of the Microchip USB stack and our PlayStation DualShock 3 application.

chipKIT programmer and the DualShock 3 have been spotted by the Kadtronix application in **Screenshot 4**. Now, we can simply plug the PID and VID values into the OTG config tool slots you see in **Screenshot 5**.

The configuration tool generates two files. The `usb_config.c` file contains the client driver function pointer table which looks like this:

```
CLIENT_DRIVER_TABLE usbClientDrvTable[] =
{
    {
        USBHostHIDInitialize,
        USBHostHIDEventHandler,
        0
    }
};
```

The `USBHostHIDInitialize` function is called by the host layer of the USB stack during enumeration. The `USBHostHIDInitialize` function code attempts to find out

all it can about the attached client device by parsing the attached device's configuration descriptor. Any HID events that are common to the HID host and attached device are handled by the `USBHostHIDEventHandler`.

The `usb_config.c` file also contains the USB embedded host Targeted Peripheral List (TPL). Our embedded USB host is "targeted" at a single predefined device. Thus, our DualShock 3 TPL utilizes those PID and VID numbers we coaxed from the PS3 controller:

```
USB_TPL usbTPL[] =
{
    { INIT_VID_PID( 0x054Cul, 0x0268ul ), 0, 0,
      {0} } // ps3_peripheral
};
```

The VID and PID in the `usbTPL` entry belongs to the DualShock you see (or don't see) in **Photo 2**.

## THE USB HOST HARDWARE

I would have used a trusty PIC18 device for this application if I could have. However, the Microchip USB stack does not support PIC18 devices in USB host mode. Although I had thoroughly thought through the DualShock design, I really was not sure I could convince the USB stack to do my bidding. Building custom USB hardware only to find out that the firmware won't work is a true bummer. So, I decided to go with an off-the-shelf solution.

I need USB host capability which is only available in the PIC24 and PIC32 microcontroller families. I nixed the Microchip Explorer route as I wanted a truly native hardware platform sans plug-in microcontrollers and interfaces. I didn't have any PIC24 boards handy, but I did have some PIC32 boards that just might work. I needed a PIC32 platform that includes a USB interface that can be forced into a host configuration. The Digilent chipKIT Max32 you see in **Photo 3** fills the bill as far as the USB-enabled PIC32MX microcontroller is concerned.

However, the chipKIT Max32 USB portal is based on an FTDI USB UART-to-bridge IC that cannot be coerced into host operation. The native USB interface of the chipKIT Max32's PIC32MX795F512L is unused. However, that unused native USB interface can easily be brought to bear with the addition of a Digilent chipKIT network shield like the one you see in **Photo 4**.

To create a suitable USB host interface, all I have to do is couple the chipKIT Max32 to the network shield and select the shield's type A USB connector (J4) via jumper JP4.

The Max32 and network shield schematic diagrams are available from the Digilent website, so we won't reproduce them here. In reality, you won't need them as the Max32 and network shield combine to form a "black box." Power for our Digilent black box is supplied by the FTDI virtual



■ **PHOTO 2.** I dare not take this PlayStation DualShock 3 outside. I'll lose it. (There is a DualShock 3 in this shot, isn't there?)

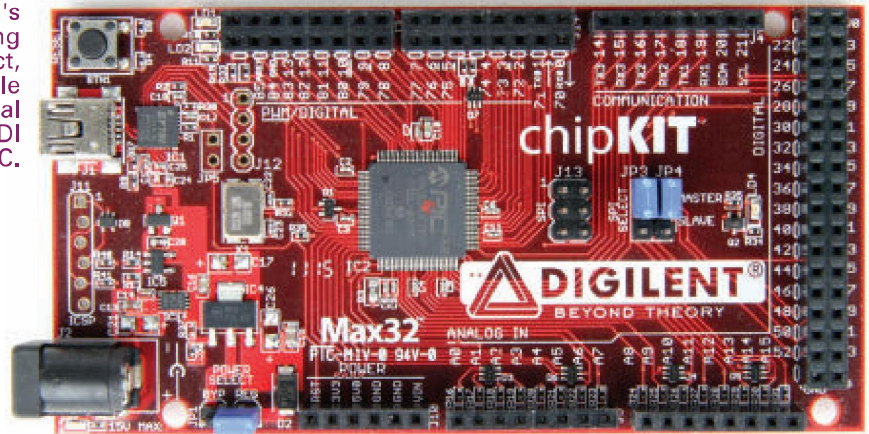


■ **PHOTO 3.** The chipKIT Max32's PIC32MX795F512L is fully capable of supporting the Microchip USB stack in host mode. In fact, the PIC32 can act as a USB host while simultaneously providing an RS-232 virtual COM port via the FTDI USB-to-UART IC.

COM port connection on the Max32. The virtual COM port is set to run at 57600 bps. The network shield host portal connects directly to the DualShock 3 USB interface. The Max32 is a no-frills PIC32 design. Its 8 MHz primary clock input is processed by PLL to produce an 80 MHz CPU/system clock and the 48 MHz USB clock. The base clocking scheme is set up in the PIC32 configuration bits:

```
#pragma config UPLLEN    = ON
// USB PLL Enabled
#pragma config FPLLMUL   = MUL_20
// PLL Multiplier
#pragma config UPLLIDIV  = DIV_2
// USB PLL Input Divider
#pragma config FPLLIDIV  = DIV_2
// PLL Input Divider
#pragma config FPLLODIV  = DIV_1
// PLL Output Divider
#pragma config FBDIV     = DIV_1
// Peripheral Clock divisor
#pragma config FWDTEN    = OFF
// Watchdog Timer
#pragma config WDTPS     = PS1
// Watchdog Timer Postscale
#pragma config FCKSM     = CSDCMD
// Clock Switching & Fail Safe Clock
// Monitor
#pragma config OSCIOFNC  = OFF
// CLK0 Enable
#pragma config POSCMOD   = HS
// Primary Oscillator
#pragma config IESO      = OFF
// Internal/External Switch-over
#pragma config FSOSCEN   = OFF
// Secondary Oscillator Enable
// (KLO was off)
#pragma config FNOSC     = PRIPLL
// Oscillator Selection
#pragma config CP        = OFF
// Code Protect
#pragma config BWP       = OFF
// Boot Flash Write
// Protect
#pragma config PWP       = OFF
// Program Flash Write
// Protect
#pragma config ICESEL    = ICS_PGx2
// ICE/ICD Comm Channel
// Select
```

■ **PHOTO 4.** All of the PIC32MX795F512L's communication peripherals are exposed by the chipKIT network shield. This time around, we're only interested in the USB host hardware portal J4 and the host connector select jumper JP4.



The 8 MHz input clock is multiplied by 20 on the PLL input side and divided by 2 at the PLL output. The USB PLL divides the incoming 8 MHz by 2 at the PLL input. The resulting 4 MHz is multiplied by 24 and divided by 2 at the USB PLL output, producing the 48 MHz USB clock. The PIC peripheral clock is equal to the 80 MHz CPU clock. The PIC clock values are made available to the DualShock application by a trio of macro definitions:

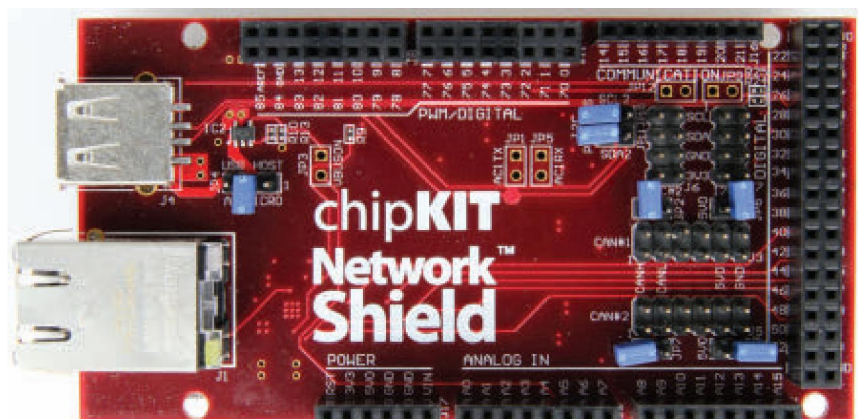
```
#define GetSystemClock()      80000000UL
#define GetPeripheralClock()  80000000UL
#define CoreTicksPerMs (GetSystemClock() / 2000)
```

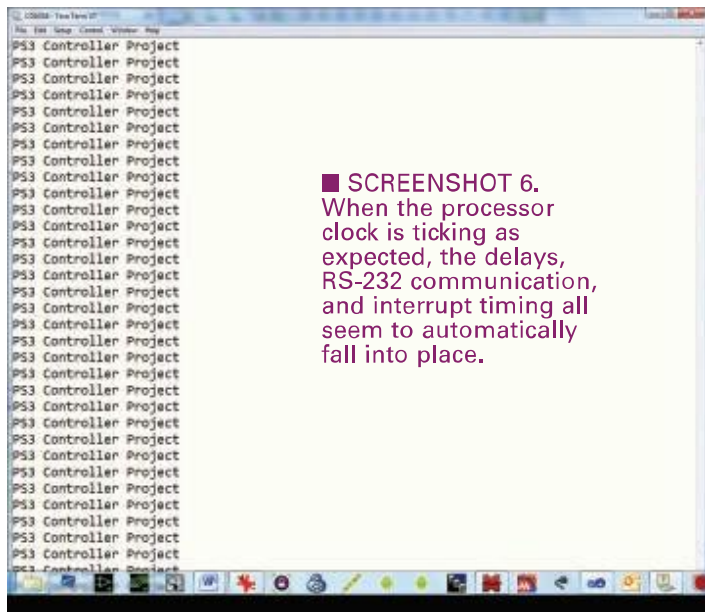
To avoid writing *for-next* timing loops, we will need an accurate delay routine. The *CoreTicksPerMs* macro is used to implement an accurate 1 mS delay function:

```
void delaysms(unsigned int ms)
{
    unsigned int msDelayTime, currentTickCnt;
    currentTickCnt = ReadCoreTimer();
    msDelayTime = (CoreTicksPerMs * ms) +
        currentTickCnt;
    while((ReadCoreTimer()) < msDelayTime);
}
```

## FIRST CONTACT ... RS-232

We are not ready to fire up the PIC32 USB engine just yet. We need to establish some basic RS-232





■ **SCREENSHOT 6.**  
When the processor clock is ticking as expected, the delays, RS-232 communication, and interrupt timing all seem to automatically fall into place.

communications over the PIC's FTDI USB portal first. The USB stack defaults to the use of UART2 for serial communication with the outside world. The Max32 is wired to feed the FTDI IC from UART1. We can't easily change the hardware, so we'll have to write some code to reroute the USB stack RS-232 data stream to UART1.

The first step is to disable buffering to *stdio*. We do that with the *setbuf* function:

```
setbuf(stdout, NULL);
```

The *\_mon\_putc()* function is defined in the XC32 libraries with a weak attribute flag. If we were to write our own *\_mon\_putc()* function code and not attach the weak attribute flag, our *\_mon\_putc()* function would always be called instead of the original XC32 library function. The *\_mon\_putc()* function is designed to write a single byte to the destination coded within it. With that, we can code a homegrown *\_mon\_putc()* function to place each byte in the PIC's UART1 transmit register:

```
void _mon_putc(char c)
{
    U1TXREG = c;
    while(U1STAbits.TRMT == 0);
}
```

In the case of our DualShock 3 USB application, every time we call the *printf* function each character is directed to *\_mon\_putc()*, which deposits the byte into U1TXREG. Now that the PIC32 UART1 drinks from the *printf* pond, we need only to initialize UART1:

```
UARTConfigure(UART1, UART_ENABLE_PINS
_TX_RX_ONLY);
UARTSetFifoMode(UART1, UART_INTERRUPT_
ON_TX_NOT_FULL |
UART_INTERRUPT_ON_RX_NOT_EMPTY);
UARTSetLineControl(UART1,
UART_DATA_SIZE_8_BITS |
UART_PARITY_NONE | UART_STOP_BITS_1);
```

```
UARTSetDataRate(UART1,
GetPeripheralClock(), 57600);
UARTEnable(UART1, UART_ENABLE_FLAGS
(UART_PERIPHERAL | UART_RX | UART_TX));
```

Some simple test *printf* code is all we need to verify our redirection setup:

```
printf("PS3 Controller Project\r\n");
```

I'll leave you with the contents of **Screenshot 6** to determine for yourself the success of our UART redirection effort.

## FIRST CONTACT ... USB

Now that we have a reliable 1 mS delay routine and RS-232 communication capability, we can try to establish basic connectivity with the DualShock 3. Our application code will run as a state machine. The first states we will code are the DualShock 3 connected and disconnected states:

```
typedef enum _APP_STATE
{
    DEVICE_NOT_CONNECTED,
    DEVICE_CONNECTED,
    READY_TO_TX_RX_REPORT
} APP_STATE;
```

```
APP_STATE PS3State;
```

Once a DualShock has been detected, we will advance to the *READY\_TO\_TX\_RX\_REPORT* state. At this point, the *READY\_TO\_TX\_RX\_REPORT* state will simply act as a place holder and will not contain any code. The USB stack provides a fitting function (*USBHostHIDDeviceDetect(1)*) that we can use to determine if the DualShock 3 is attached to the host or not:

```
void DetectPS3(void)
{
    if(!USBHostHIDDeviceDetect(1))
    {
        PS3State = DEVICE_NOT_CONNECTED;
    }
}
```

The *USBHostHIDDeviceDetect(1)* argument of 1 denotes the device address. Since there is only one device that will ever be attached, the device address defaults to 1. Let's write some USB stack code that attempts to reach out to the PS3. The target result of this code snippet is to simply command the DualShock to make a simple USB connection to the host Max32:

```
BOOL DisplayConnectOnce = FALSE;
BOOL DisplayDetachOnce = FALSE;
int main (void)
{
    BYTE i;
    init(); //initialize chipKIT
           //Max32
    USBInitialize( 0 ); //Initialize USB
                       //layers
```

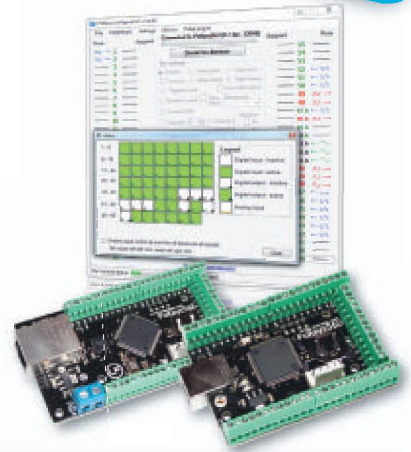


Following the initialization of the chipKIT Max32 hardware that is performed by the *init()* function, we must initialize the USB stack. This initialization is performed by the *USBInitialize(0)* function. The *USBInitialize(0)* function must be called before any USB stack processing can occur:

```
do{
    USBTasks();
    //do USB housekeeping
    DetectPS3();
    //look for PlayStation DualShock 3
```

Our DualShock 3 detect code snippet will run as a never-ending *do-while* loop. The state machine will churn inside of the loop. Each time the loop is

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traversed, we must call *USBTasks()* to allow the USB stack to take care of business. Once the stack has done its chores, we can continue our quest to find an attached DualShock 3:

```
switch(PS3State)
{
    case DEVICE_NOT_CONNECTED:
        USBTasks();
        if(DisplayDetachOnce == FALSE)
        {
            printf("PS3 Detached\r\n");
            DisplayDetachOnce = TRUE;
        }
        if(USBHostHIDDeviceDetect(1))
        {
            PS3State = DEVICE_CONNECTED;
            DisplayConnectOnce = FALSE;
        }
        break;
```

If the *DEVICE\_NOT\_CONNECTED* state is active, we allow the USB stack to do some housekeeping before sending the *PS3 Detached* message to the Max32's USB-to-UART bridge IC. To prevent the message from repeating itself every time we loop, the *DisplayDetachOnce* flag is set to TRUE. The next logical thing to do is look for an attached DualShock 3 using the *USBHostHIDDeviceDetect(1)* function. If a DualShock responds, we change the active state to *DEVICE\_CONNECTED* and set the *DisplayConnectOnce* flag:

```
case DEVICE_CONNECTED:
    PS3State = READY_TO_TX_RX_REPORT;
    if(DisplayConnectOnce == FALSE)
    {
        printf("PS3 Connected\r\n");
        DisplayConnectOnce = TRUE;
        DisplayDetachOnce = FALSE;
    }
    break;
```

If a DualShock was found, the next time through the *do-while* loop the state machine will be in the *DEVICE\_CONNECTED* state. The state machine will be advanced to the *READY\_TO\_TX\_RX\_REPORT* state. If we have not transmitted the *PS3 Connected* message, we do so within the *DEVICE\_CONNECTED* state and set the message transmission flags accordingly:

```
case READY_TO_TX_RX_REPORT:
    //Do nothing here. This allows a change of
    //connection state to occur and be
    //reported.
    break;
```

The *READY\_TO\_TX\_RX\_REPORT* state allows the state machine to enter a state other than *DEVICE\_CONNECTED* or *DEVICE\_NOT\_CONNECTED*. So, when we install a USB cable between the Max32 host and PS3, the *PS3 Connected* message will be transmitted. The *PS3 Connected* message will only be sent once and the state machine will fall into the *READY\_TO\_TX\_RX\_REPORT* state until the USB cable is removed.

With the USB cable removed, the state machine will enter the *DEVICE\_NOT\_CONNECTED* state, transmit the *PS3 Detached* message, and fall into the *READY\_TO\_TX\_RX\_REPORT* state:

```
}
}while(1);
}
```

The *PS3State* transitions will occur forever or until power is removed from the Max32 host.

## NEXT TIME

We will force the DualShock 3 to spit out the status of all its buttons and joysticks. Once we have that data, we can use it to control just about anything the Max32 can touch with its I/O pins and communications peripherals.

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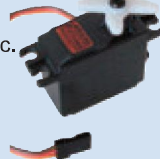
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## LED PHOTOMETERS REVISITED

**Back in November 2007, I wrote an article about LEDs as the active element of a photometer. As you may recall, photometers are devices that measure the intensity of light. The best photometers measure light intensity for very specific colors of the spectrum. Quality photometers can therefore cost a bundle. However, Forrest Mims developed a way of using LEDs in reverse to measure light intensity. While the resulting photometer may not have as narrow a response as the highest quality photometers, LEDs make affordable photometers a reality. This month's article shows a significantly better design for the LED photometer than my 2007 article did.**

### LEDS IN REVERSE

Nearly everyone is familiar with light emitting diodes, or LEDs. You supply them a current and they emit a very pure color of light. Which color an LED emits depends on the energy gap of the semiconductor, which is a result of the substrate's doping. The wider the gap, the greater the energy released when the electron recombines with a hole on the other side. So, therefore, the higher the energy of the photon released.

What Forrest Mims found out is that this process can be reversed. That is, when a photon of light strikes the gap, it separates an electron from the hole and creates a small current flowing out of the LED. In a way, this might not be too surprising. This is what happens with photodiodes and solar cells (solar cells are photodiodes optimized for power production). It appears, however, that no one had tested this effect in LEDs before.

Mims also discovered that the photon must have the same frequency that the LED emits in order to push an electron across the gap. In other words, LEDs produce a current in response only to photons of the same frequency that they emit.

The output from a photodiode or LED is a current proportional to the number of photons striking the gap per second. Voltage is not the output of the LED because each photon

produces a single electron, and all electrons have the same charge ( $1.6 \times 10^{-19}$  coulombs). Since the intensity of light shining on the LED is a measure of the number of photons striking the LED per second and each photon liberates an electron of identical charge, incident light produces a current proportional to its intensity.

If we measure the current flowing out of the cathode of an LED, then we can determine the intensity of the light shining on the LED, but only in the wavelength of light that the LED normally emits. That's the definition of the photometer.

### PRACTICAL LED PHOTOMETERS

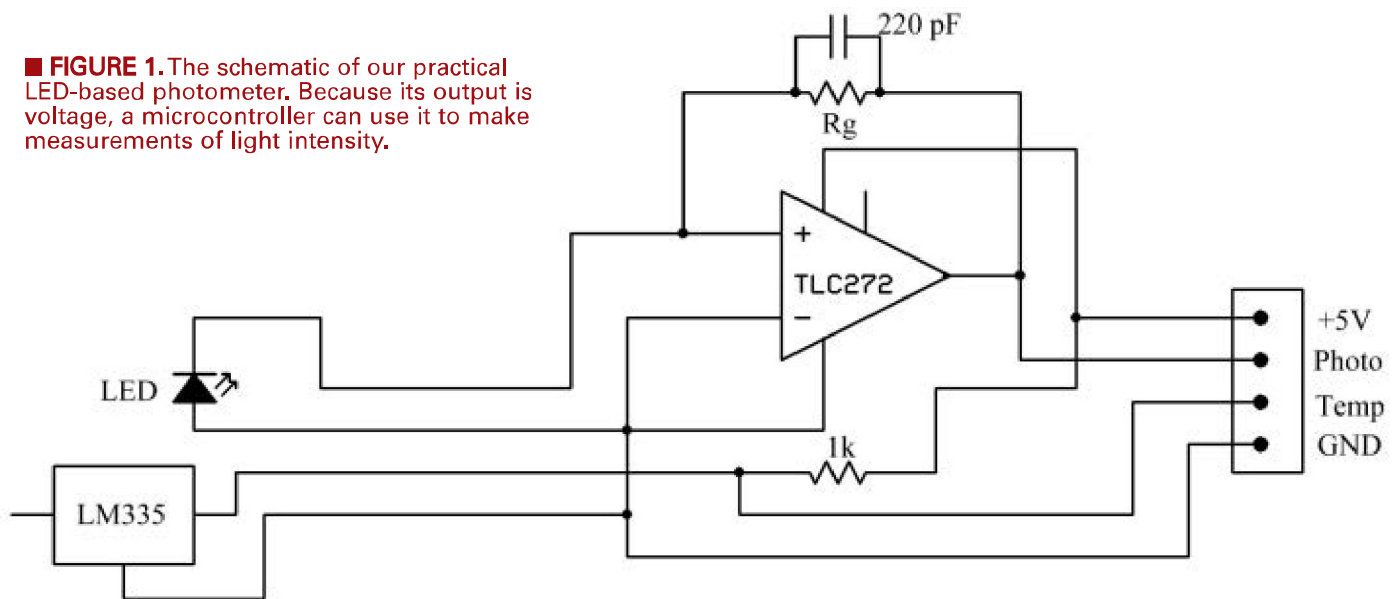
For any instrument to be practical in near space, its output must be a voltage that the flight computer can measure. That's because microcontrollers can't directly measure current.

Microcontrollers like the PICAXE can measure voltage using their analog voltage to digital value conversion, while other microcontrollers like the BASIC Stamp rely on an analog-to-digital conversion (ADC) IC to do the same thing for them. Therefore, we must convert the LED's output current into a voltage that is proportional to the amount of current.



Discuss this article in the *Nuts & Volts* forums at <http://forum.nutsvolts.com>.

■ **FIGURE 1.** The schematic of our practical LED-based photometer. Because its output is voltage, a microcontroller can use it to make measurements of light intensity.



There is a simple circuit that can do this: the transimpedance amplifier.

After a little research (thank goodness for the Internet) and emailing Mr. Mims, I found the inexpensive transimpedance amplifier circuit for the LED photometer.

At the heart of the transimpedance amplifier is the TLC272 operational amplifier, or op-amp, which is inexpensive and available from companies like Jameco, Mouser, and Digi-Key.

The transimpedance amplifier makes use of inverting feedback to convert an input current into an output voltage proportional to the value of the feedback resistor. Since the input is a current and the output is a voltage, the transimpedance amplifier is said to have a gain measured in ohms.

So, for example, a transimpedance amplifier with a gain of one kilo-ohm converts a 1.0 mA input current into an output voltage of 1.0 volts.

The current output of the typical LED is very small; therefore, the transimpedance amplifier requires a large value feedback resistor to create a practical output voltage.

I have found that a 100 kilo-ohm resistor is needed for IR LEDs and a

one mega-ohm resistor is needed for visible color LEDs.

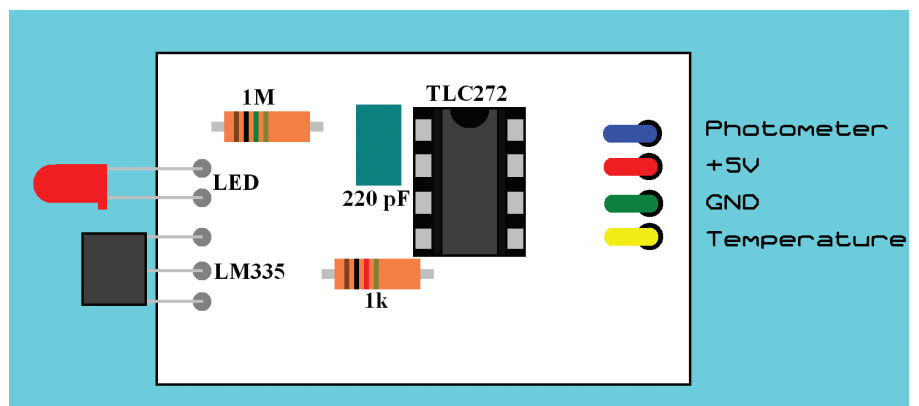
You need to know one other thing about LED-based photometers: Their current output is sensitive to their temperature. Therefore, it is important to know the temperature of the LED. I think the easiest way to do this is to mount an LM335 temperature sensor next to the LED.

The LM335 is basically a temperature controlled zener diode, which means its voltage output is proportional to its temperature. Our practical LED-based photometer now has two outputs: the light intensity measurement and the temperature.

## CONSTRUCTION

Create the single-sided printed circuit board (PCB) for the circuit from the pattern that is available at the article link. If you are unable to produce PCBs at home, then assemble the photometer on perf board using the **schematic** provided here. If you can create the PCB, then you can follow **Figure 2** for the proper placement of the components.

Start the construction by first selecting an LED for the photometer. Be sure to make note of its peak frequency which is normally given



■ **FIGURE 2.** This shows the placement of components for this article's PCB mask.

## PARTS LIST FOR THE LED-BASED PHOTOMETER

220 pF capacitor  
1 M $\Omega$  resistor for red, green, or blue LEDs and 100 k $\Omega$  resistor for an IR LED  
1k $\Omega$  resistor  
TLC272 op-amp  
Eight-pin socket  
LED  
LM335  
24 gauge stranded wire  
Cable termination appropriate for your microcontroller circuit

when you purchase the LED. In a pinch, you can find this information in the LED's datasheet. If the LED is infrared, then the feedback resistor will have a value of 100 kilo-ohms. If the LED is any other color, then use a one mega-ohm or higher resistor for feedback.

You will know the photometer needs a higher feedback resistor value if the output voltage is too small when the photometer is pointed at the sun. Next, file the top of the LED flat and then use fine sandpaper to give the top of the LED a frosted flat surface. Flattening the top of the LED like this removes the lens from the top and makes it a little less sensitive to its pointing direction.

Now, solder all the components except the LM335 and the LED to the PCB. You can solder in any order as there is nothing tricky about the design that makes soldering order important. Do not insert the TLC272 into the IC socket until after the socket is soldered to the PCB.

The design requires both the LM335 and the LED to extend beyond the PCB at a 90 degree angle. You'll notice that the LED extends a bit farther away than the LM335. This lets you add a sun shield to the photometer in an attempt to limit the temperature changes it experiences.

The proper orientation of the LED can be gleaned from the **placement diagram**. As for the LM335, its flat face is turned forward. Fold the leads on the LM335 and the LED prior to soldering the leads. This makes sure they extend their proper distance beyond the edge of the PCB or perf board.

### CABLING

At this point, you need to cable the PCB for your microcontroller circuit. Four wires are required — +5 volts, ground, temperature output, and photometer output — to connect the photometer to a microcontroller. Solder four 24 gauge wires to the PCB and route them through the strain relief holes at the end of the PCB. Using the strain relief holes prevents the wires from breaking off

the PCB as a result of normal use. **Figure 3** illustrates strain relief holes I made in a perf board.

Many microcontroller boards have I/O ports for connecting external circuits like sensors. The photometer's two outputs — named photometer and temperature — must connect to inputs that the microcontroller can digitize. The +5 volt and ground wires must connect to where the microcontroller board can provide the five volts needed to operate the photometer.

How you terminate the wires in the photometer cable depends on your microcontroller board. However, in many cases, you will be able to solder the bare ends of the wires to a two by three male header and then plug the header into an I/O port.

The last step is to make a sun shield. The shield is a sheet of white plastic foam that will reflect excess heat from the sun and insulate the LED from the greatest changes in temperature. I recommend using white polystyrene foam.

You can purchase this as a product called Cellfoam 88 from many hobby and craft stores. Cut out a two inch square of foam and drill a 1/4 inch diameter hole into the sheet where the LED will look out. Then, use hot glue to attach the Styrofoam sunshield to the LED and LM335. The LM335 will remain covered while only the flat tip of the LED will be able to look out of the sun shield.

That completes the construction of the photometer. Next time, we'll test and calibrate the photometer circuit.

Onwards and Upwards,  
Your near space guide **NV**



■ **FIGURE 3.** I enlarged four holes in this perf board to accommodate insulated wires. The ends of the wires were soldered to pads closer to the IC.



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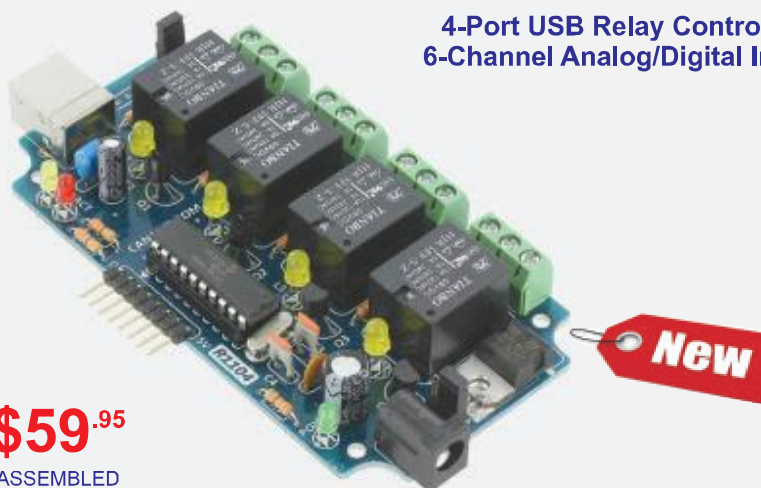


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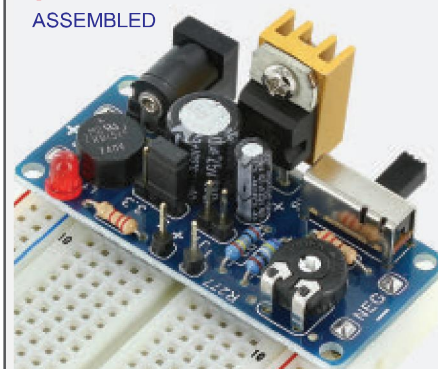
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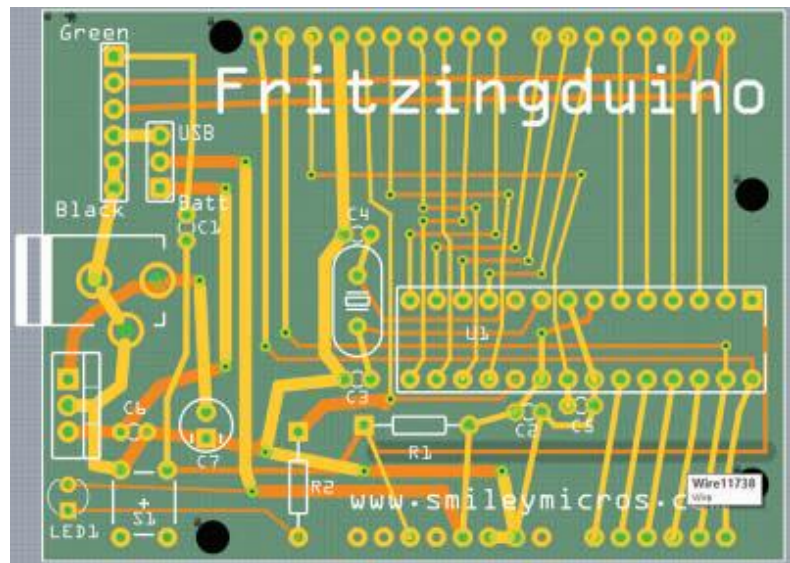
# SMILEY'S

## #58 WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

# FRITZINGDUINO

**Please keep in mind that we are several Workshops into the discussion of an Arduino Fritzing prototype to production project using an Arduino alarm clock as an example. Arduino is a novice-friendly microcontroller development system; Fritzing is a novice-friendly electronic design system — breadboard to schematic to printed circuit board (PCB). Using these together provides a complete novice-friendly path from that 'AH HA!' moment when the concept leaps into your mind, to the final physical realization of the concept.**



■ FIGURE 1. Fritzingduino PCB layout.

We are using an alarm clock design as a substitute for 'AH HA!' since this concept covers many aspects of general microcontroller systems. We are learning how to write the software both for the PC and the Arduino for our alarm clock, and we are learning how to make the hardware first on an Arduino shield, and then — using Fritzing — we are learning to design our own PCBs for the project.

The end goal will be a single PCB of our own design (using Fritzing) that incorporates the Arduino circuits (without requiring an Arduino) along with the DS1307 RTC (real time clock) alarm clock circuits. This board will work with our PC and Arduino code to provide not only a working alarm clock — but more important — the knowledge needed to log data and to control devices at

known intervals — the basis for most embedded systems projects.

Last month, we finished the Process\_Alarms module in the Arduino alarm clock software and looked in detail at the accuracy of the DS1307 RTC. This month, we are going to split the article between software and hardware. We will first see how to make our RTC more accurate, and then we will jump back into the hardware where we will take all this stuff we've been learning about using Fritzing for Arduino shield designs and figure out how to incorporate both the Arduino core circuits and the shield circuits into a single design using a single PCB — in effect, we will learn how to roll our own Arduino. (Whew!)

## MAKING THE DS1307 RTC MORE ACCURATE

Last month, we began looking at the accuracy of the DS1307 RTC and ways to calibrate it so that it will be more accurate. We learned that it can be off by up to + or - 1.7 seconds per day. That's almost 12 seconds per week, or 10-1/2 minutes per year. Does this matter? Well, if you are plugging your AAC (Arduino Alarm Clock) into a PC every few days and recalibrating it, then probably not. After all, what's a few seconds among friends? However, if you are going to set this thing as some sort of data logger that goes unattended for months, then yes it probably will matter. It really depends on the application.

Last month, I claimed that I thought I could make this thing as accurate as the more expensive and accurate DS3234 that has a built-in temperature compensated crystal. The modest folks at SparkFun call their breakout board for this chip "DeadOn RTC - DS3234." So, we can take it that the rated  $\pm$  two minutes per year is DeadOn. Will ours do this? I think so, but I'll have to run one for a few months to get an idea. So maybe, maybe not. As they say, time will tell.

Also last month, we approached calibration by watching the RTC and the PC for a week or so to see how far off the clock drifted. We then derived the number of seconds that passed for each second that the RTC drifted, and whether that drift was + or -. We called these seconds *calSeconds* and manually entered them into the 'calibration seconds' box in the PCAAC application.

My first inclination was to calibrate by having the RTC adjusted each time it got off by a second. Unfortunately, I kept running into walls doing that, mostly due to me over-thinking the whole thing. Finally, after wasting too much time debugging, I decided to leave the RTC alone and simply calculate the seconds it is off each time the time is requested. This turns out to be fairly simple (ahem!). All we need to know is the last time the RTC was calibrated by the PC, the number of seconds in which the RTC gains or loses a second, whether it is, in fact, a gain or loss, and if the calibration has been set:

**calSeconds** — The number of seconds it takes the RTC to gain or lose a second.

**lastSet** — The 32-bit *unixtime* that the RTC was last set to the PC time.

**addSubtract** — Whether the RTC is gaining or losing seconds.

**callsSet** — Has the calibration been set?

These values are saved to the EEPROM and each time the Arduino starts up, it accesses these values to use



■ FIGURE 2. Arduino alarm clock.

along with the RTC time to calculate the calibrated time. Calculating the 'real' real time is simply a matter of subtracting the *lastSet* time from now to get the number of seconds since the last time the PC calibrated the RTC. Then, we divide the seconds elapsed by the *calSeconds* (the number of seconds that it takes the RTC to gain or lose a second) to get the number of seconds the RTC is off. [Okay, stop and think ... read it again, think some more ... got it? Thought so.]

More mathish: 'now' minus 'last time set by the PC' divided by 'seconds gained or lose a second' equals 'seconds gained or lost':

$$\text{Seconds gained or lost} = (\text{Now} - \text{lastSet}) / \text{calSeconds}$$

We can then look at *addSubtract* to see if we need to add or subtract these seconds to get our adjusted real time. Of course, we only want to do this if the calibration has, in fact, been done. So, we should check *callsSet* and make sure it is true before doing the calibration. Then, depending on whether you are gaining or losing, you get the adjusted time by adding or subtracting *adjustSeconds* from what the lying RTC is saying now.

The Arduino proto shield alarm clock kit lets you build an alarm clock circuit on a breadboard and port that circuit to a PCB. This kit is the basis for my presentation of how to do a complete Arduino design cycle using Fritzing to go from a breadboard prototype, through schematic creation and breadboard layout, and finally producing your own printed circuit board. You can get the kit or materials that support this learning activity from the *Nuts & Volts* webstore.



Or, more Arduinish code:

```
DateTime now = RTC.now();
uint32_t adjustedTime, adjustSeconds;

adjustSeconds = (now.unixtime() - lastSet)
/calSeconds;

if(addSubtract) adjustedTime = now.unixtime() -
adjustSeconds;
else adjustedTime = now.unixtime() +
adjustSeconds;
```

You might think that it would make sense to adjust the RTC to the calibrated time. This is actually what I have beat my head against the wall trying to do for days before throwing in the towel (quite bloody towel). Think about it for a few minutes and this little step becomes more complex. When do you do the calibration?

Well, you could do it each time *calSeconds* passes, but this means you'll need an alarm set to *calSeconds* and then you add or subtract a second from the RTC and reset *lastSet* to now. Simple, huh?

Let me suggest that if you want to do it this way, you either have a better brain than I do or have a large stock of towels to soak up the blood from bashing your head in the proverbial wall. (Heck, maybe I'm just getting old.)

If somebody wants to do this and test it and send me a copy, I'll send that person a slightly used towel as a reward. In the meantime, let's look at the code I finally did get working.

## THE CALIBRATION ARDUINO SOFTWARE

The PCAAC first sets the RTC to the correct time (in the PC's opinion) using the 'P' command before it sends the calibration data using the 'c' command. The *parseArray()* function in the Arduino Commander module first receives that P command and time data to set the RTC, then receives the c case, and calls the *calibrate()* function that follows:

```
void calibrate(){
  #if defined(DEBUG)
    Serial.println(F("calibrate()"));
  #endif
  uint8_t val1,val2,val3,val4;

  // Get the four bytes for the 32-bit Unix time
  val1 = commandArray[1];
  val2 = commandArray[2];
  val3 = commandArray[3];
  val4 = commandArray[4];

  // Create the 32-bit calibration value from the
  // 4 bytes
  calSeconds = (uint32_t)val1 + \
    ((uint32_t)(val2)<<8) + \
    ((uint32_t)(val3)<<16) + \
    ((uint32_t)(val4)<<24);

  // Get the add or subtract variable
  addSubtract = commandArray[5];
```

```
// Set calibration to active
calIsSet = 1;

// Use 0 to turn it off the calibration alarm
if(calSeconds == 0){
  calIsSet = 0; // Calibration is no longer
  active
  Serial.println(F("Stop calibration"));
  return;
}

// Get the date and time from the DS1307
DateTime now = RTC.now();
// Load this into the initial last_cal variable
lastSet = now.unixtime();

// Save values to EEPROM
writeCalibration();

// Inform the PC
Serial.print(F("calSeconds = "));
Serial.println(calSeconds);
Serial.print(F("addSubtract = "));
Serial.println(addSubtract);
Serial.print(F("lastSet = "));
Serial.println(lastSet);
}
```

This function extracts the *calSeconds* and *addSubtract* variables from the *commandArray[]* data sent from the PC. It then sets *calIsSet* to true, and gets the current time into *lastCal*. It calls the *writeCalibration* function which records these variables into the EEPROM as follows:

```
void writeCalibration(){
  #if defined(DEBUG)
    Serial.println(F("writeCalibration"));
  #endif
  uint8_t val1,val2,val3,val4;

  val1 = (uint8_t)(calSeconds & 0x000000FF);
  val2 = (uint8_t)((calSeconds & 0x0000FF00)>>8);
  val3 = (uint8_t)((calSeconds & 0x00FF0000)>>16);
  val4 = (uint8_t)((calSeconds & 0xFF000000)>>24);
  EEPROM.write(CAL_EEPROM_ADDRESS,val1);
  EEPROM.write(CAL_EEPROM_ADDRESS+1,val2);
  EEPROM.write(CAL_EEPROM_ADDRESS+2,val3);
  EEPROM.write(CAL_EEPROM_ADDRESS+3,val4);

  writeLastSet();

  EEPROM.write(CAL_EEPROM_ADDRESS+8,calIsSet);
  EEPROM.write(CAL_EEPROM_ADDRESS+9,addSubtract);
}

void writeLastSet(){
  uint8_t val1,val2,val3,val4;

  val1 = (uint8_t)(lastSet & 0x000000FF);
  val2 = (uint8_t)((lastSet & 0x0000FF00)>>8);
  val3 = (uint8_t)((lastSet & 0x00FF0000)>>16);
  val4 = (uint8_t)((lastSet & 0xFF000000)>>24);
  EEPROM.write(CAL_EEPROM_ADDRESS+4,val1);
  EEPROM.write(CAL_EEPROM_ADDRESS+5,val2);
  EEPROM.write(CAL_EEPROM_ADDRESS+6,val3);
  EEPROM.write(CAL_EEPROM_ADDRESS+7,val4);
}
```

I separated out a function to write the *lastSet* value because I write this to EEPROM each time I set the RTC from the PC. Remember that sending the calibration seconds and setting the RTC to the current PC time are two separate concepts and operations.

Each time the Arduino is reset and runs *Setup()*, it calls the *readCalibration()* function to get these variables:



■ FIGURE 3. FTDI USB to TTL converter cable.

```
void readCalibration(){
  #if defined(DEBUG)
    Serial.println(F("readCalibration"));
  #endif
  calSeconds = (uint32_t)EEPROM.read(
    (CAL_EEPROM_ADDRESS) + \
    ((uint32_t)EEPROM.read(
      (CAL_EEPROM_ADDRESS+1)<<8) + \
      ((uint32_t)EEPROM.read(
        (CAL_EEPROM_ADDRESS+2)<<16) + \
        ((uint32_t)EEPROM.read(
          (CAL_EEPROM_ADDRESS+3)<<24);
  lastSet = (uint32_t)EEPROM.read(
    (CAL_EEPROM_ADDRESS+4) + \
    ((uint32_t)EEPROM.read(
      (CAL_EEPROM_ADDRESS+5)<<8) + \
      ((uint32_t)EEPROM.read(
        (CAL_EEPROM_ADDRESS+6)<<16) + \
      ((uint32_t)EEPROM.read(
        (CAL_EEPROM_ADDRESS+7)<<24);

  calIsSet = EEPROM.read(CAL_EEPROM_ADDRESS+8);
  addSubtract = EEPROM.read(CAL_EEPROM_
    ADDRESS+9);
}
```

With this code, the Arduino can now calculate the adjusted real time as follows:

```
void showAdjustedTime()
{
  if(calIsSet){
    DateTime now = RTC.now();
    uint32_t adjustedTime, adjustSeconds;

    adjustSeconds = (now.unixtime() -
      lastSet)/calSeconds;
```

```
    if(addSubtract) adjustedTime = now.unixtime()
      - adjustSeconds;
    else adjustedTime = now.unixtime() +
      adjustSeconds;

    DateTime temp(adjustedTime);

    Serial.print(F("ATIM"));
    Serial.print(temp.hour(), DEC);
    Serial.print(':');
    Serial.print(temp.minute(), DEC);
    Serial.print(':');
    Serial.print(temp.second(), DEC);
    Serial.println(TERMINATOR);
  }
  else Serial.println("ERROR: showAdjustedTime -
    calIsSet is 0");
}
```

This function first checks to see if the calibration has been set and if not, it tells the PC that there is an error. If *calIsSet* is true, it then calculates the adjusted seconds by subtracting the *lastSet* time from the current time to get the number of seconds since the last calibration, and divides that number by the number of seconds that it takes to gain or lose a second. Let's repeat what we showed earlier:

```
adjustSeconds = (now.unixtime() -
  lastSet)/calSeconds;
```

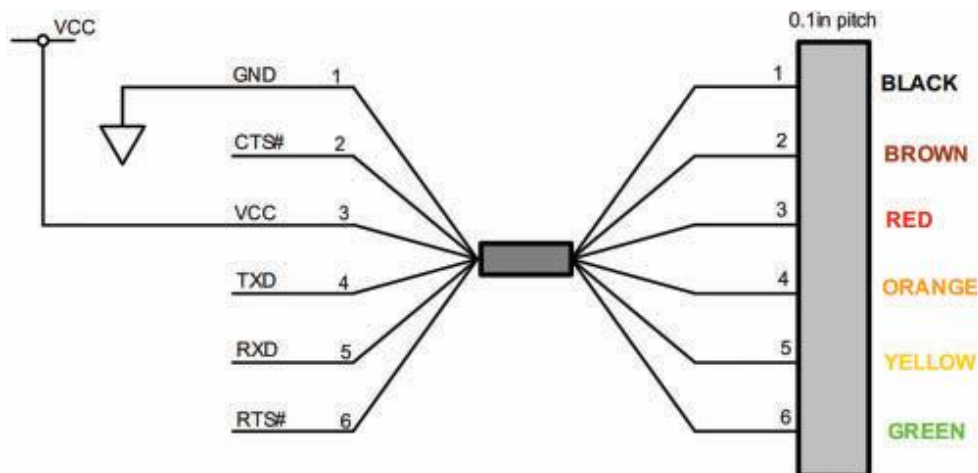
Next — depending on *addSubtract* — it calculates the adjusted time by either adding or subtracting the indicated number of seconds. Finally, it converts that value from *unixtime* to *DateTime* and sends the adjusted time to the PC.

[Last minute aside: We manually calculate the *calSeconds* in the above discussion. Just before press time, I started working on a technique to automate this process to make the alarm clock even more accurate. I'll add documentation about this to the version of this Workshop that goes on my blog.]

We are now finished with our discussion of the Arduino alarm clock software (is that applause I'm hearing?). Please note that you and I will both find bugs in this code, so it will evolve. Be sure and check the article

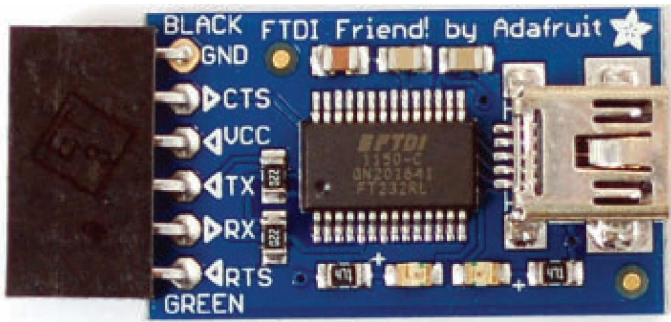
reprints on **www.smileymicros.com** for the latest version of this code.

Now, let's continue with our Arduino Fritzing prototype to production discussion by moving on to the next step toward hardware production. We will learn to roll our own Arduino — the Fritzingduino — then, next month we will combine it with our alarm clock design to make our very own production single PCB design for an Arduino based alarm clock.

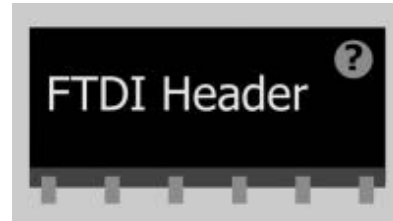


■ FIGURE 4. FTDI USB to TTL.





■ FIGURE 5. Adafruit FTDI Friend.



■ FIGURE 6. Fritzing FTDI USB to TTL header.

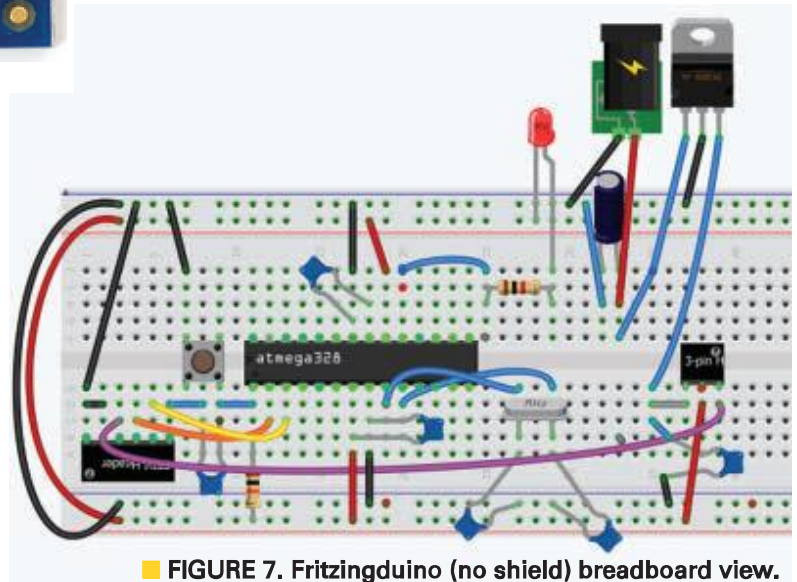
## ROLL YOUR OWN ARDUINO

Why would you want to do this? Arduinos from the actual Arduino folks are cheap [<http://arduino.cc/en/Main/Products>]. Arduino compatible clones from all over the planet are even cheaper [though not necessarily as reliable as the 'real' thing. Also, no money goes to the Arduino core team for further development of the Arduino, so please consider buying from the Arduino folks.] There is simply no way that you are going to build an Arduino cheaper than you can buy one (if your time accounts for anything). Further, if the Arduino doesn't do exactly what you want, you can get shields for it and there is almost certainly somebody selling a shield that will do what you want for less than you can roll your own — so why bother?

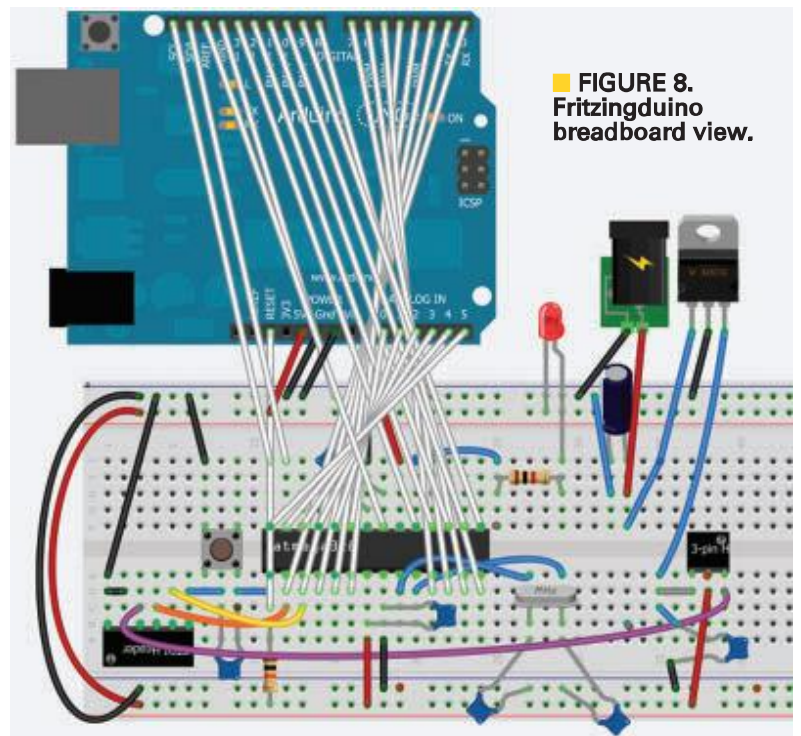
Well firstly, you might, for instance, want to add something to the Arduino board that nobody else is making at the moment. Or, secondly, you might just want to learn how to do it because you are one of those pesky curious folks who just wants to know how to do stuff. And, thirdly, you might want to combine your shield design with the minimum Arduino circuitry all on a single PCB. In which case, you might save some money by rolling your own. There might even be a fourthly or fifthly, but whatever '#ly' your reason is, let's start rolling.

### Specifying a Minimum Arduino

I'm not sure anybody knows exactly what a minimum Arduino is. It probably should have a microcontroller with an Arduino compatible bootloader that can communicate with the IDE (Integrated Development Environment), can use the Arduino library, and can be identified in the IDE Tools\Board list. Also, if it is to make claims about being PCB compatible, it should probably have the exact header pin layout for one of the Arduino boards so that it can use standard shields. It probably should also have some way to provide power to the board besides the USB connection. So, let's specify a minimum Arduino that will work like an Arduino UNO R3, have the standard pinout,



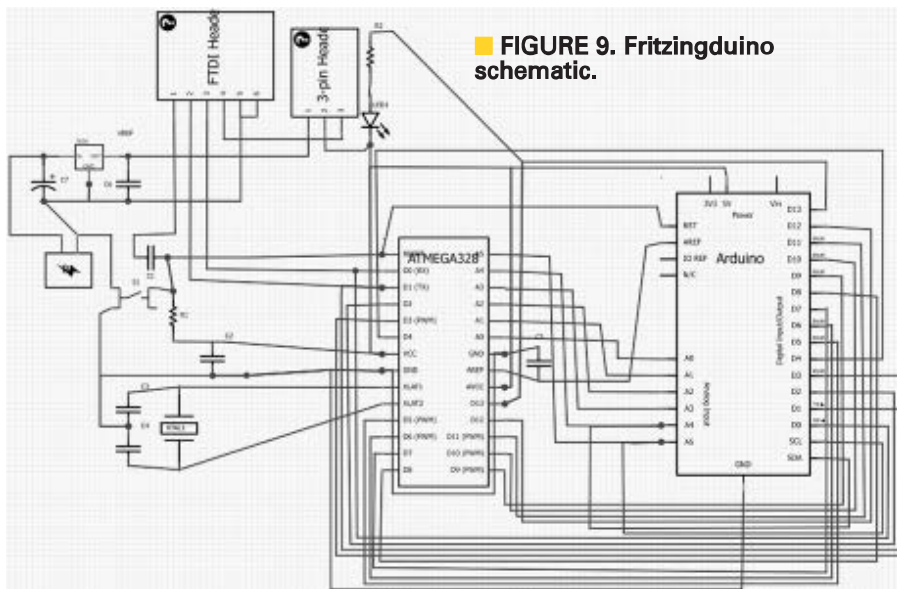
■ FIGURE 7. Fritzingduino (no shield) breadboard view.



■ FIGURE 8. Fritzingduino breadboard view.

and take external battery power through a barrel connection to provide the needed voltage:

1. Atmega328 with Arduino bootloader in memory.
2. PCB with the Arduino UNO R# header pin layout.



■ FIGURE 9. Fritzingduino schematic.

3. USB connection.
4. Barrel power connection and voltage regulator for external power.

## Outsourcing the USB

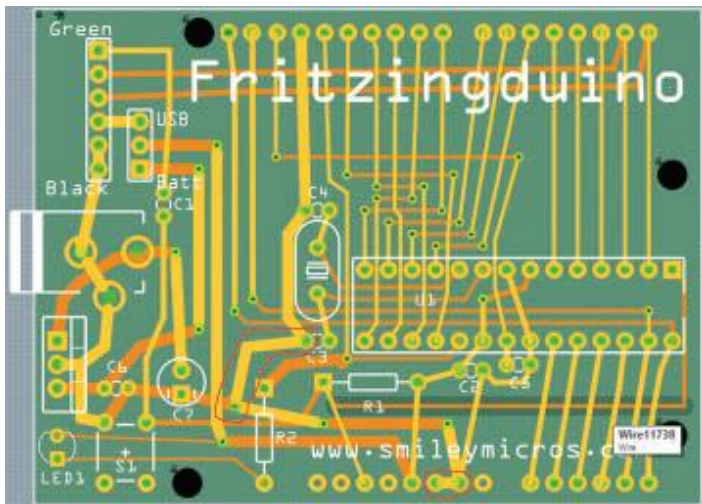
Way back in the April 2010 issue of *Nuts & Volts*, we discussed building an Arduino on a breadboard. In the May 2010 Workshop, we saw how to use an FTDI virtual serial port header compatible with the FTDI cable shown in **Figure 3** with the wiring shown in **Figure 4**.

There are lots of USB to TTL boards available that use the original FTDI pinout, for instance, the Adafruit FTDI Friend shown in **Figure 5**. [If you want to get into the details of FTDI converters, you can learn a lot from my book, *Virtual Serial Port Cookbook*.]

We can create an FTDI USB to TTL part in Fritzing using the mystery part shown in **Figure 6** (creating parts from the mystery part was discussed in the January 2013 Workshop). We will use this to provide USB communication and power for our Fritzingduino design.

## Fritzingduino is Based on BreadboArduino

We will base our Fritzingduino design on the BreadboArduino (discussed in Smiley's Workshop 21). We'll build this on a large breadboard in Fritzing as shown in **Figure 7**. Next, we add the Arduino shield connectors. There are a lot of wires here and the board looks pretty hairy (as you can see in **Figure 8**). The figure is a bit deceptive in that it looks like we are adding an Arduino to our board, but the Arduino in the figure actually only adds



■ FIGURE 10. Hand routing required.

Label	Part Type	Properties
C1,C2,C3,C4,C5,C6	Ceramic Capacitor	CAPACITOR 0.1 $\mu$ F, 100 VOLT X7R, 10% RADIAL 5.08 MM BULK, JAMECO #544884
C7	Electrolytic Capacitor	CAPACITOR, RADIAL, 47 $\mu$ F, 16V, 20%, 85C, 5 x 12 x 5 MM, JAMECO #1946244
H1	Header - 6 pins 90 degree	HEADER, RIGHT ANGLE MALE, 1 ROW, 6-PIN, .1 INCH CTR, .025 INCH PST, .27 INCH GOLD T(10), JAMECO #2076851
H2	Header - 3 pins Straight	HEADER, .1 INCH STRAIGHT MALE, 1 ROW, 6-PIN, .025 INCH PST, .23 GOLDTAIL - BREAK FOR THREE-PIN HEADER, JAMECO #153700
J1	Shorting block	SOCKET, SHORT BLACKS, BLACK, CLOSE, (10), PACKAGE OF 10 - ONLY NEED ONE - JAMECO #19141
LED1	Red LED - 3 mm	LED UNICOLOR RED, 697 NM, 2-PIN, T-1, JAMECO #697565
P1	Power plug	JACK, DC POWER, MALE, 2.1 MM, SOLDER, SOLDER TERMINAL, JAMECO #101178
R1	10K $\Omega$ Resistor	RESISTOR, CARBON FILM, 10K OHM, 1/4 WATT, 5%, (BAG OF 10), JAMECO #2157167
R2	1K $\Omega$ Resistor	RESISTOR, CARBON FILM, 1K OHM, 1/4 WATT, 5%, (BAG OF 10), JAMECO #2157159
S1	Pushbutton	SINGLE POLE SINGLE THROW PUSHBUTTON TACTILE SWITCH, JAMECO #153251
U1	ATMEGA328	EIGHT-BIT WITH 32 KB FLASH MEMORY ONBOARD ATMEL AVR MICROCONTROLLER (MCU), JAMECO #2139111
VREF	Voltage Regulator - 5V	STANDARD REGULATOR 5 VOLT, 1A, 3-PIN, (3+TAB), TO-220, JAMECO #51262
XTAL1	Crystal	16.000 MHz HC49/S CRYSTAL, JAMECO #137891

**Table 1. "Roll Your Own Arduino" Bill of Materials.**



the shield connectors that we'll need for the schematic and PCB. All those wires hide some of the breadboard, but when you are in the breadboard view in Fritzing you can move the Arduino around and the wires move with it. So, if you can't get at something on the breadboard, you can move the Arduino around until the section of the breadboard you want is accessible.

This board is fairly difficult to wire properly in Fritzing. There were many times I thought I'd made a connection and I hadn't. The schematic shown in **Figure 9** also shows this complexity. You must be very careful to make sure you first understand what every connection is about and that each one is made properly. When you finish, you'll have the PCB design shown back in **Figure 1**. Just be warned that even if the PCB passes the design rule check, it still doesn't mean you've wired it correctly. **DOUBLE-CHECK EACH CONNECTION!** This is a pain, but once you've got it right, then you've got the basis for all your future homebrew Arduino projects.

## ONE MINOR PROBLEM

One minor problem that might have become a major problem: As you can see from the breadboard view in **Figure 8**, I used the Arduino UNO to get the shield pins for the PCB layout. I got it all wired up and did the design rule check, and it said the board was ready for production. However, I noticed that the horizontal trace from C3 to C4 to the upper shield GND pin wasn't connected to the rest of the ground traces! What's going on? Is this a bug in Fritzing?

Well, feeling slightly embarrassed, I posted this as a bug on the Fritzing forum and found out immediately (thanks Jonathan Cohen from Fritzing) that the bug was in my wetware, not Fritzing. I was using the Arduino UNO for the shield pins, but the Arduino UNO has the upper and lower shield pin grounds connected on the board. So, if this were a shield design, it would have worked just fine since the grounds would be connected through the Arduino board.

Since it isn't a shield design, it is meant to replace the Arduino in a shield design, so I'm responsible for where each of the shield pins goes.

Fortunately, only grounds were a problem and I was able to connect a trace between C3 and the rest of the ground lines. I also had to connect the two lower ground pins together. These two added connections are circled in red in **Figure 10**. Just remember to double-check your grounds if you try to repeat my method for getting the UNO shield pins. Next month, we will learn how to put an Arduino bootloader on a raw Atmega328 so that we can finish rolling our own Arduino. Then, we will port the alarm clock circuit to the PCB so that we have a single board that combines an Arduino + shield. **NV**

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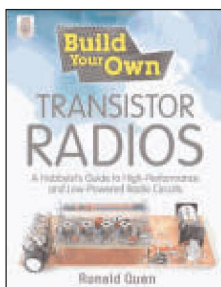
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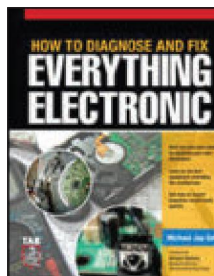
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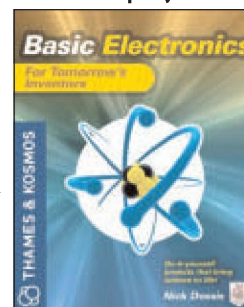
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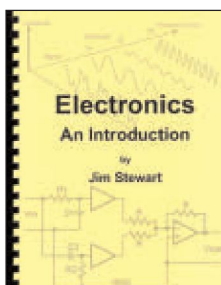


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by Jim Stewart

This book is designed as an in-depth introduction to important concepts in electronics. While electronics can be highly mathematical, this text is not about calculations. It is about how electronic equipment is able to extract, process, and present information held in electrical signals. If you are in — or studying to be in — a profession that requires the use of electronic equipment, then this book will provide the insight necessary to use such equipment effectively.

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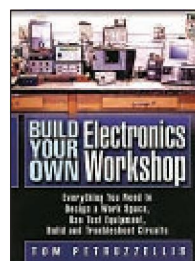
by Thomas Petruzzellis

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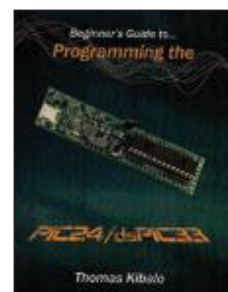
### Beginner's Guide to ... Programming the PIC24/dsPIC33

by Thomas Kibalo

Kibalo takes you step by step through the fundamentals of programming the PIC24H which can equally be applied to the dsPIC33. His clear explanation of the inner workings make learning the PIC24H/dsPIC33

16-bit architecture easy. His code examples demonstrate how to perform the functions most applications require. The hardware is shown in a simple breadboard setup so even a beginner can build it, along with very few extra components needed.

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### HTML: A Beginner's Guide

by Wendy Willard

Create highly functional, impressive websites in no time. Fully updated and revised, *HTML: A Beginner's Guide*, Fourth Edition explains how to structure a page, place images, format text, create links, add color, work with multimedia, and use forms. You'll also go beyond the basics and learn how to save your own web graphics, use Cascading Style Sheets (CSS), create dynamic web content with basic JavaScript, and upload your site to the web. By the end of the book, you'll be able to build custom websites using the latest HTML techniques.

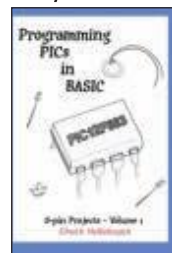
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### Programming PICs in Basic

by Chuck Hellebuyck

If you wanted to learn how to program microcontrollers, then you've found the right book! Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the Basic software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **\$14.95**



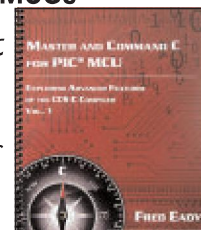
### Master and Command C for PIC MCUs

by Fred Eady

*Master and Command C for PIC MCU, Volume 1* aims to help readers get the most out of the Custom Computer Services C compiler for PIC microcontrollers.

The author describes some basic compiler operations that will help programmers particularly those new to the craft create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call (output\_bit) can serve as a basic aid to let programmers know about the "health" of their PIC code.

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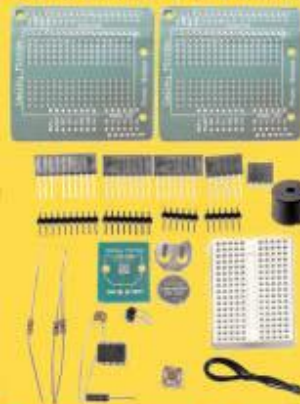
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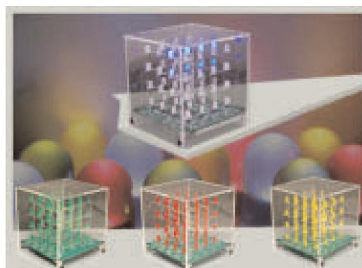
### Geiger Counter Kit



This kit is a great project for high school and university students. The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr. The LND712 tube in our kit is capable of measuring alpha, beta, and gamma particles.

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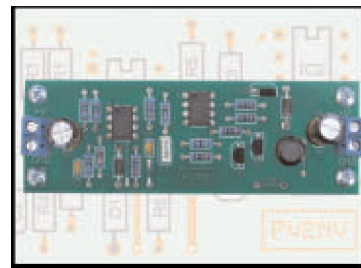
### 3D LED Cube Kit



This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes. Colors available: Green, Red, Yellow & Blue

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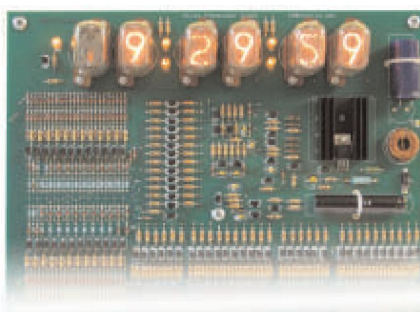
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If you need +12V and -12V, but all that's available is +12V, then this project is for you. The inverted DC-DC converter gives you -V out when you put +V in, and works over a range of voltages without adjustment. It's an easy to build voltage mirror that can supply over 100 mA without a significant drop in voltage.

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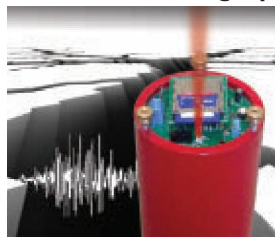
### Neon Transistor Clock Kit



*Add HIGH VOLTAGE to your clock!*  
 This is a Nixie Tube display version of the Transistor Clock. It uses only discrete components — no integrated circuits. For more info, see the April 2012 issue.

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### Seismograph Kit

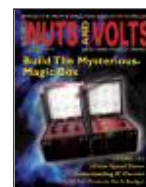


**As seen in the May 2012 issue.**  
 Now you can record your own shaking, rattling, and rolling.

The Poor Man's Seismograph is a great project /device to record any movement in an area where you normally shouldn't have any. The kit includes everything needed to build the seismograph. All you need is your PC, SD card, and to download the free software to view the seismic event graph.

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### Magic Box Kit



**As seen on the April 2007 cover.**

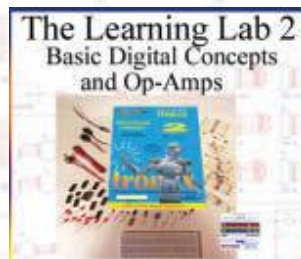
This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

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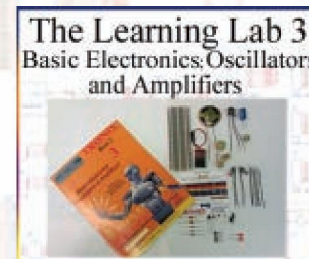
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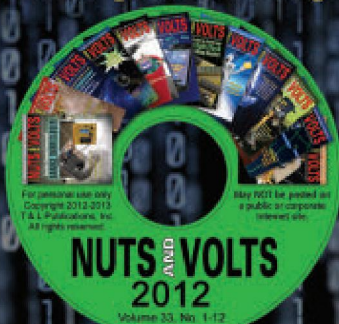
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## >>> QUESTIONS

### Cell Phone Detection

I work at a counseling center where it's best to limit phone calls for the mental well-being of the residents. Is there any way to detect a cell phone in the building, either by an available device or a homebrewed circuit? Is there a way to find a hidden or lost cell phone? Is there a way to log cell phone presence, signal usage, and strength? Just show whether there was a signal, the time, and the strength (how close).

#5131

**Leroy Sensenig**  
Penn Yan, NY

### Wireless Pushbutton

I built a Jeopardy game console for use in a classroom setting. The console works quite well and can accommodate up to four players or teams. The issue I have is that the

player buttons are attached to the console via cables and this gets cumbersome in class. I'd like to find a wireless solution where the push of a button would wirelessly close an associated relay in the console. I've looked at commercial solutions and they are all north of \$200. Can anyone suggest a circuit that I could use that would be relatively inexpensive and easy to build? I would be willing to consider a commercial solution but, as I said, all the ones I've found so far are out of my price range.

#5132

**Pete Schestopol**  
Atlanta, GA

### Unknown IC

Figure 1 is a schematic I drew of the IC in question. I have not been able to find any IC that would connect in this circuit. There is only a date code on it. Nothing else at all. Pin 6 is

obvious, but with pin 5 to ground and pin 7 not connected, I am stumped. The only IC I thought it could be is a serial Flash memory. Any other suggestions?

#5133

**Daniel Zielinski**  
Port Saint Lucie, FL

### Movement Logging Circuit

Can someone make an experimental circuit that uses a motion detector? I want to feed the signal to a microcontroller for logging movement or object identification.

#5134

**George Fred Powelson**  
Ogden, UT

### Antenna Shortening

How do you make a ham radio antenna shorter with a coil? For a dipole or yaggi.

#5135

**George Fred Powelson**  
Ogden, UT

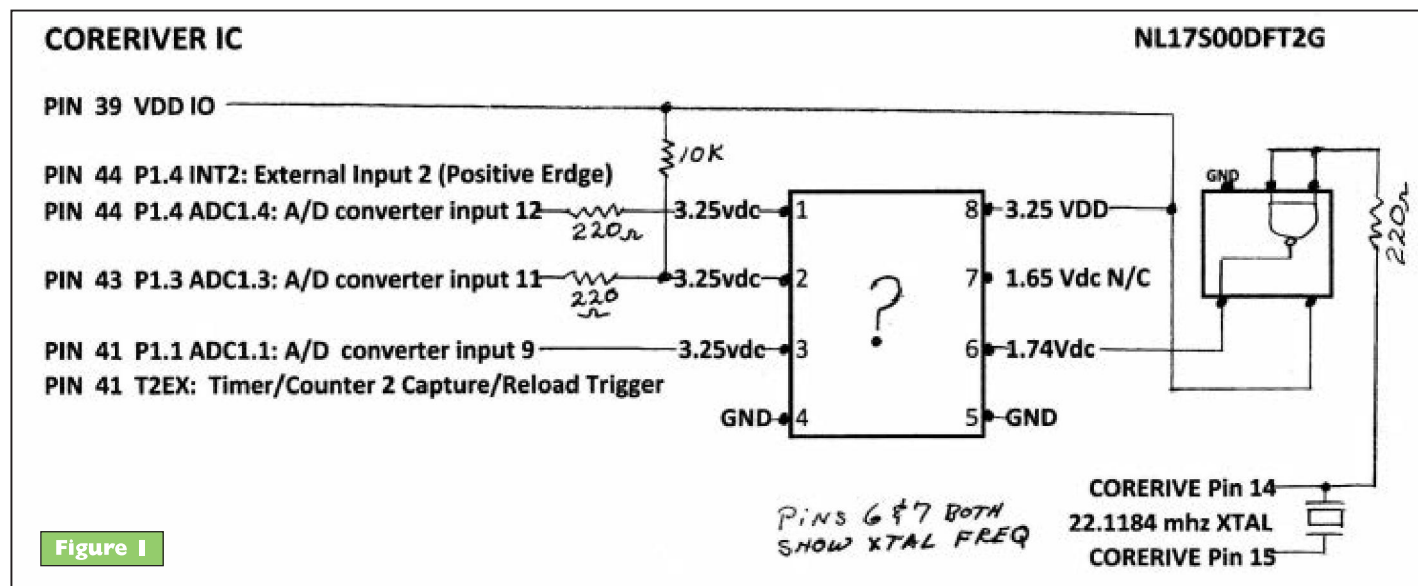


Figure 1

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## >>> ANSWERS

### [#3132 - March 2013]

*I lost my hearing at a very young age and have always struggled with listening to the audio out phones, computers, MP3 players, etc. When I have my hearing aids in and try to listen, it's actually worse!*

*I would like to build an audio amplifier with a programmable equalizer, to be connected to the 3.5 mm audio output jack. I will connect +5V separately.*

*The device will be connected to a PC temporarily through the USB jack for programming, and then be removed.*

Here are my questions:

*Is a one stage amplifier enough?*

*Is it better to amplify first then equalize, or equalize then amplify?*

*Who makes the best audio chips?*

*What software is needed to program the EQ?*

*Any suggested readings, websites, software, forums, etc.*

Specifications:

*Easy to build and program using a chip like Monolithic Linear integrated circuit LA3600; [www.electronic-lab.com/blog/?tag=equalizer](http://www.electronic-lab.com/blog/?tag=equalizer).*

*Input voltage: 5V*

*Gain: ?*

*Equalizer: Seven band or better*

*Output: 3.5 mm*

*And for the hard way, using a DSP or FPGA to build an advanced equalizer/gain headset that could be used in any computer, phone, or MP3 player!*

An audio amplifier with a graphic equalizer doesn't require a DSP or FPGA. Quickfilter Technologies ([www.quickfiltertech.com](http://www.quickfiltertech.com)) sells a variety of chips aimed specifically at audio applications. The company also has development kits and a neat GUI. No programming needed. A USB cable provides a link between a development board and a PC used to set parameters.

The Quickfilter QF3DFX chip includes a 10-band parametric

equalizer and an eight-band graphic equalizer. Cypress Semiconductor's Programmable System on a Chip (PSoC) families ([www.cypress.com](http://www.cypress.com)) include filter blocks, and a graphical drag-and-drop GUI makes it easy to configure a system. These chips include ADCs and DACs, so I bet Monito could create what he wants with only a PSoC chip and a couple of audio amplifier ICs. Find a useful app note at [www.cypress.com/?docID=21352](http://www.cypress.com/?docID=21352), and info about a 10-band graphic equalizer at [www.cypress.com/?rID=43672](http://www.cypress.com/?rID=43672).

**Jon Titus**  
Herriman, UT

### [#4131 - April 2013]

*I have two Fuji Film digital cameras (FinePix 2650 and FinePix A210). Each came equipped with a 16 MB xD-Picture card (image memory card) which is a semiconductor memory (NAND-type Flash memory) to record digital image data.*

*I have a microSD adapter (orange) with a 1 GB card which fits EXACTLY into the xD-Picture card slot. Even though I formatted the card INSIDE the cameras several times, I'm still getting "Card Error - Card Not Initialized" messages on the camera's LCD monitors.*

*Why can't I use this 1 GB microSD adapter with these digital cameras? Under what circumstances can I use this type of adapter?*

**#1** You have two problems. The first is SD and XD cards are not interchangeable.

Problem number 2 is the only compatible cards for your cameras per the user manuals are as follows:

#### **FinePix2650**

DPC-16 (16 MB)  
DPC-64 (64 MB)  
DPC-32 (32 MB)  
DPC-128 (128 MB)

#### **FinePixA210**

DPC-16 (16 MB)  
DPC-32 (32 MB)

DPC-64 (64 MB)  
DPC-128 (128 MB)  
DPC-256 (256 MB)

So, your SD card and adapter will not work, and your cameras will not accept a 1 GB card.

**Joe Fulton**  
Youngstown, OH

**#2** The simple answer is that the memory card you are trying to use is too big for the camera[s]. I looked in the manuals available online — the max size allowed is 128 MB for the 2650, and 256 MB for the A210.

Neither camera can handle the 1 GB you're trying to use. You need to find smaller capacity microSD cards. You might try to only format 128 MB [or 256 MB] and see if that works [not sure if you can do that with XD or SD memory cards].

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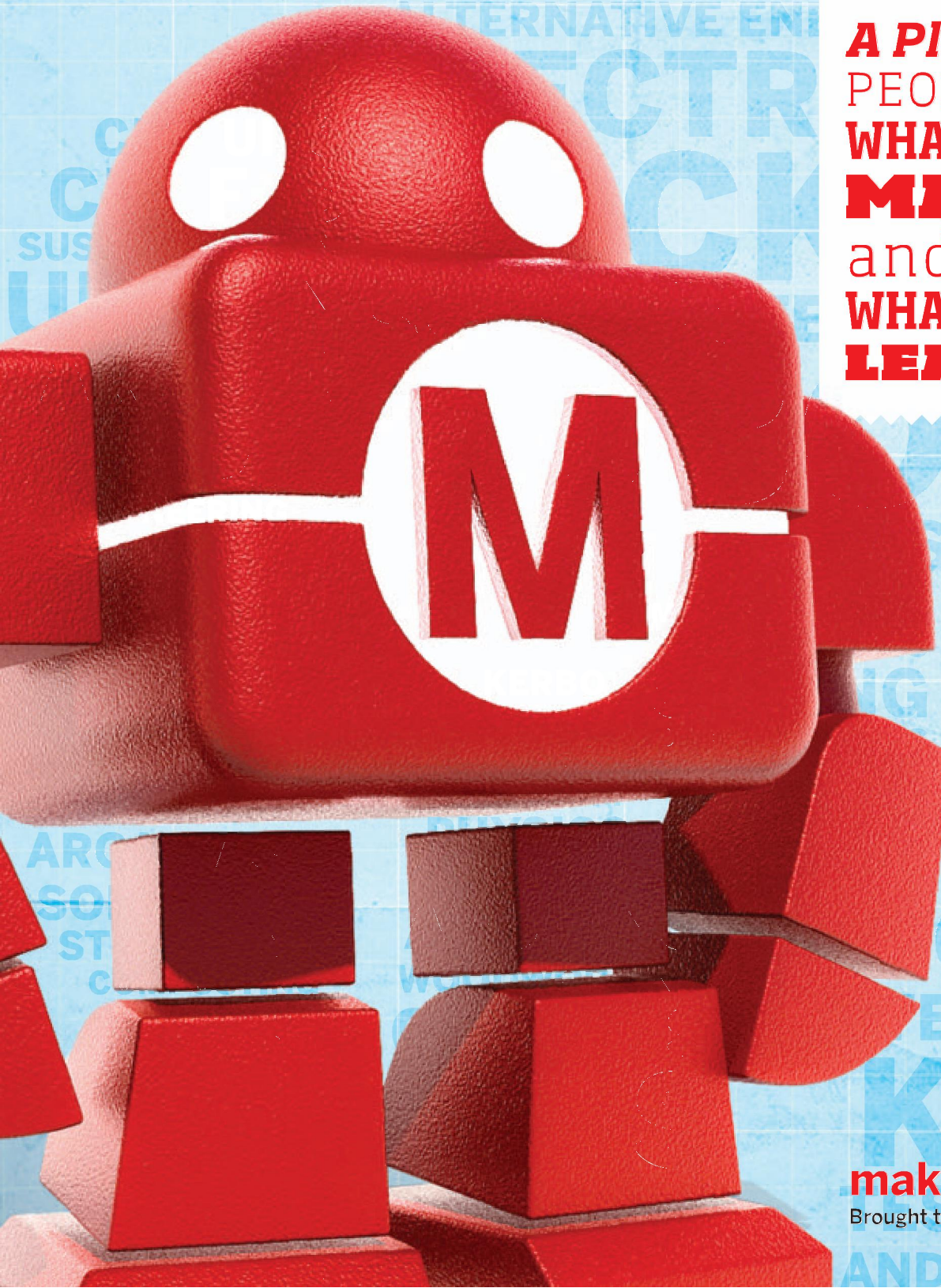
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- ✓ True stereo control keeps virtual sonic source location intact!
- ✓ Auto-bypass restores original levels when power is turned off!
- ✓ Unbalanced RCA and 3.5mm stereo input and output line level jacks!
- ✓ Built-in bar graph indication of signal level with display mute!

The SGC1 is one of our latest kits, and provides a great solution to the age-old problem: how can we easily correct inconsistent audio levels without negatively affecting the dynamics of the audio signal? The SGC1 circuit implements a principle known as the "Platform Gain Principle," which was originally developed by CBS Labs (what we now know as CBS in the TV and radio world) to allow transmitted audio levels to be automatically adjusted to keep them within a desired range.

Think of it like an audio engineer, constantly adjusting the output level in order to limit highs that would be too loud while boosting lower levels so that they can still be heard. You may think "oh, this is just another limiter/compressor!" Not so! Here's the real trick: keeping the full dynamic range ratio of the output signal the same as the original input - something the typical limiter/compressor can only dream of doing! The SGC1 can be placed in just about any standard analog stereo line level audio circuit (the red and white RCA connectors or the mini-phone connector) to keep the audio level within the desired range. It's also the perfect addition to any of our hobby kit transmitters, allowing you to match levels between different audio sources while keeping lows audible and preventing the highs from overdriving.

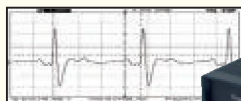
The SGC1 makes a great addition to any audio system where you need to keep levels from different sources under control, but still make sure they all sound great! In addition to its useful basic function and great audio performance, the SGC1 also boasts a front panel LED meter to give an indication of the relative level of the input signal, plus a level control (also on the front panel) that allows you to adjust the controller to the min/max center point of your desired level range. And yes, it is a **Stereo Gain Controller!** Meaning that the levels of both the left and right channels are monitored and adjusted equally, thereby maintaining the relative virtual position of things like instruments, singers and speakers! The entire unit is housed in a slim attractive black textured aluminum case that is sure to complement your studio or home theatre. If you're looking for perfect audio levels, hire a broadcast audio engineer, but if that doesn't fit your budget, the SGC1 is the next best thing! Includes 15VDC world-wide power adapter.

**SGC1 Stereo Audio Platform Gain Controller Kit**

**\$179.95**

### Electrocardiogram ECG Heart Monitor

- ✓ Visible and audible display of your heart rhythm!
- ✓ Bright LED "Beat" indicator for easy viewing!
- ✓ Re-usable hospital grade sensors included!
- ✓ Monitor output for professional scope display
- ✓ Simple and safe 9V battery operation



Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Safe 9V battery operation.

**ECG1C Electrocardiogram Heart Monitor Kit With Case & Patches**  
**ECG1WT Electrocardiogram Heart Monitor, Factory Assembled & Tested**  
**ECGP10 Electrocardiogram Re-Usable Probe Patches, 10-Pack**

**\$44.95**  
**\$89.95**  
**\$4.95**

### Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.



**V51 Voice Switch Kit**

**\$9.95**

### Logic Interface Module

Interface your digital output to the real world with an on-board SPDT relay rated at 240V at 10A! It takes a digital low (.5VDC or less) or a high (+1 to +12VDC) and provides your choice of an active low or high closure! It's that simple! Runs on 12VDC at 60mA.



**R11 Logic Interface Kit**

**\$17.95**

### Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.



**ABM1 Passive Aircraft Receiver Kit**

**\$89.95**

### Laser Trip Sensor Alarm

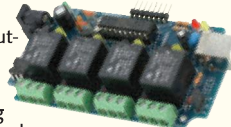
True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

**LT51 Laser Trip Sensor Alarm Kit**

**\$29.95**

### 4-Channel USB Relay Control

This professional quality USB relay controller allows computer controlled switching of external devices, plus full bi-directional communication with the external world using the USB port of your computer!



The controller features four onboard relay outputs with a current rating of 10A each. Also onboard is a 6-channel Input/Output interface, with each channel individually configurable as Digital Input, Digital Output, Analog Input (10-bit Resolution). In Digital Input/Output modes, each channel can support a TTL compatible or ST input or a 5V output signal. In Analog Input mode, each channel can convert a voltage of between 0 to 5V into a 10-bit digital representation.

**UK1104 4-Ch USB Relay Interface Kit**

**\$59.95**

### Four-Mode Keyless Entry Test Set

Just like the days of "plugs, points, and condenser" are over, so are the days of having the hardware store grind out a spare key for your car!



Now when your keyless access system doesn't work, you need to accurately detect what part of the system is malfunctioning. This could be anything from a dead battery in the key fob, a "brain-dead" key fob, to malfunctioning sensors, antennas, or other system components in the vehicle. Until now there was no way to determine where the system was failing.

Testing your system is easy. To test the complete 125 kHz/315 MHz communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob.

The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set.

If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! Runs on a standard 9V battery. Also available factory assembled & tested.

**WCT3 Keyless Entry Test Set Kit**

**\$59.95**

### Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.



**IG7 Ion Generator Kit**

**\$64.95**

### HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

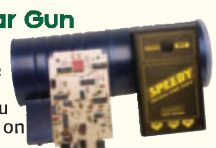


**PG13 HV Plasma Generator Kit**

**\$64.95**

### Speedy Speed Radar Gun

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC121 supply.



**SG7 Speed Radar Gun Kit**

**\$74.95**

### Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.



**PR2 Broadband RF Preamp**

**\$69.95**

### Van de Graaff Generators

Create your own lightning with these time tested student favorites! Produces low current static currents that can be "shocking" but perfectly safe! Draw sparks to a screwdriver, grab hold and watch your hair stand straight up! Two models produce from 200kV to 400kV!



**VG Van de Graaff Generators from \$139.95**



Get the brand new 2013 Ramsey Hobby Catalog today! Filled with some of the newest goodies around! Order yours today... Or download the PDF at [www.ramseykits.com/catalog](http://www.ramseykits.com/catalog)!

**Follow Us and SAVE \$\$**

Follow us on your favorite network site and look for a lot of super deals posted frequently... exclusively for our followers!





## 8-Channel Remote Ethernet Controller



Now you can easily control and monitor up to 8 separate circuits via the standard Ethernet network in your home or office. Connection wise it couldn't be simpler. The controller functions as an IP based web server, so it can be controlled by any internet browser that can reach your network! There are no drivers or proprietary software required, just access the controller like any web page from your PC, laptop, or even your smartphone! Security is assured allowing up to 4 separate user credentials. The controller can be set to a specific static IP within your network subnet or can be set to DHCP (auto negotiate). The controller can even be programmed to send you an email to notify and confirm power up and status changes!

To simplify the connection of your equipment to the controller, 8 separate and isolated relay outputs are provided! This gives you internet or network control of up to 8 separate functions. No need to worry about interfacing a logic high or logic low, or burning up the interface! The applications are endless! From something as simple as turning on and monitoring lights at your house with a normal latched closure to advanced control of your electronic gadgets, radio equipment, or even your garage door! Each relay contact is rated at 12A at 30VDC or 16A at 230VAC. Each of the 8 channels has built-in timer and scheduler programs for day, weekend, working days, every day, and every day except Sunday. Relay control functions are programmable for on, off, or pulse (1-99 seconds, 1-99 minutes, or 1-99 hours). In addition to control functions, the web interface also displays and confirms the status of each channel. Each channel can be custom labeled to your specific function name. The controller operates on 12VDC or 12VAC at 500mA or our new AC121 global 12VDC switching power supply below. Factory assembled, tested, and ready to go! Even includes a Cat-5 cable!

VM201 8-Channel Remote Ethernet Controller, Factory Assembled & Tested

\$169.95

## Laser Beam Audio Communicator



\*Now you can talk to your friends over one of the most secure long-distance transmission types available, a laser beam! The transmitter uses a microphone or external audio to modulate a laser beam on and off at a rate of more than 16kHz so the audio fidelity is much better than that of a standard 3kHz telephone line!

The receiver includes filtering to remove the 16kHz carrier and leave behind the high quality audio, and then boost its level for use with earphones. Transmitter audio AGC keeps your level perfect! Includes transmitter, receiver and laser pointer. Each runs on a 9V battery (not included).

LBC6K Laser Beam Audio Communicator Kit

\$59.95

## 5A PWM Motor Speed Controller

This handy controller uses a pulse width modulated output to control the speed of a motor without sacrificing torque! Handles a continuous current of 5A and includes LED to indicate speed as well as an oversized gold heatsink! Also available factory assembled.

CK1102 5A PWM Motor Controller Kit \$14.95

## Digital LED Thermometer

This handy thermometer reads Celsius or Fahrenheit on an eye-catching .56" LED display! Based on the DS18B20 sensor and controlled by a PIC, it has a range of -67°F to 257°F (-55°C to 125°C) with a wired remote range of 325 feet!

CK127 Digital LED Thermometer Kit \$29.95

## Tone Encoder/Decoder

Encode and decode with the same kit! This little mini-kit will simultaneously encode and/or decode any audio frequency between 40Hz and 5,000 Hz! Precision 20-turn trim pot adjustment! 5-12VDC.

TD1 Tone Encoder/Decoder Kit \$9.95

## Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 Tickle Stick Kit \$9.95

## Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

L51 Laser Light Show Kit \$49.95

## Optically Isolated Module

The hobbyist's headache solver! Converts any AC or DC signal to logic level. The beauty is that the input and output are totally isolated from each other! Output can drive up to 150mA at 40VDC.

OM2 Optically Isolated Module Kit \$16.95

## Water Sensor Alarm

This little \$7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 Water Sensor Alarm Kit \$6.95

## Touch Switch

The ultimate touch switch! Touch once - it's on, touch again - it's off, or use the momentary outputs that stay on only as long as touched. Two switch circuits on each board. Drives loads up to 100mA. Runs on 6-12VDC.

TS1 Touch Switch Kit \$9.95

## Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C Tri-Field Meter Kit \$74.95

## Electret Condenser Mic

This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 Mini Electret Condenser Mic Kit \$3.95

## 12VDC Regulated Switching Supply

Go green with our new 12VDC 1A regulated supply. Worldwide input 100-240VAC with a Level-V efficiency! It gets even better, includes DUAL ferrite cores for RF and EMI suppression. All this at a 10 buck old wallwart price! What a deal!

AC121 12VDC 1A Regulated Supply \$9.95

## 12VDC Worldwide Supply

It gets even better than our AC121 above! Now, take the regulated Level-V green supply, bump the current up to 1.25A, and include multiple blades for global country compatibility! Dual ferrite cores!

PS29 12VDC 1.25A Global Power Supply \$19.95

## Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Saint, eats 2-8VAC or 9-12VDC, it's not fussy!

K2655 Electronic Watch Dog Kit \$39.95

## Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 Sniff-It RF Detector Probe Kit \$27.95

## Classic Nixie Tube Clocks HOT SELLER!



Our next generation of classic Nixie tube clocks perfectly mesh today's technology with the Nixie era technology of the 60's. Of course, features you'd expect with a typical clock are all supported with the Nixie clock... and a whole lot more!

The clocks are programmable for 12 or 24 hour mode, various AM/PM indications, programmable leading zero blanking, and include a programmable alarm with snooze as well as date display, 4 or 6 tube, kit or assembled!

We then jumped the technological time line of the 60's Nixie displays by adding the latest multi-colored LEDs to the base of the Nixie tubes to provide hundreds of illumination colors to highlight the glass tubes! The LED lighting can be programmed to any color and brightness combination of the colors red, green, or blue to suit your mood or environment.

Then we leaped over the technological time line by integrating an optional GPS time base reference for the ultimate in clock accuracy! The small optional GPS receiver module is factory assembled and tested, and plugs directly into the back of the clock to give your Nixie clock accuracy you could only dream of!

The clocks are available in our signature hand rubbed Teak & Maple, polished aluminum, or clear acrylic bases. You also have your choice of IN-14 or highly sought after IN-8-2 nixie tubes (for the 6-tube clock).

NIXIE Classic Nixie Tube Clock Kits From \$229.95

GET THE NUTS & VOLTS DISCOUNT!

Mention or enter the coupon code **NVRMZ12** and receive 10% off your order!

800-446-2295  
www.ramseykits.com

Prices, availability, and specifications are subject to change. We are not responsible for typos, stupid, printer's bleed, or upcoming summer dreams that just aren't materializing! But like Phil, Robin says early spring and nice summer, so there is hope! Visit [www.ramseykits.com](http://www.ramseykits.com) for the latest pricing, specials, terms and conditions. Copyright 2013 Ramsey Electronics®... so there!

RAMSEY ELECTRONICS®

590 Fishers Station Drive

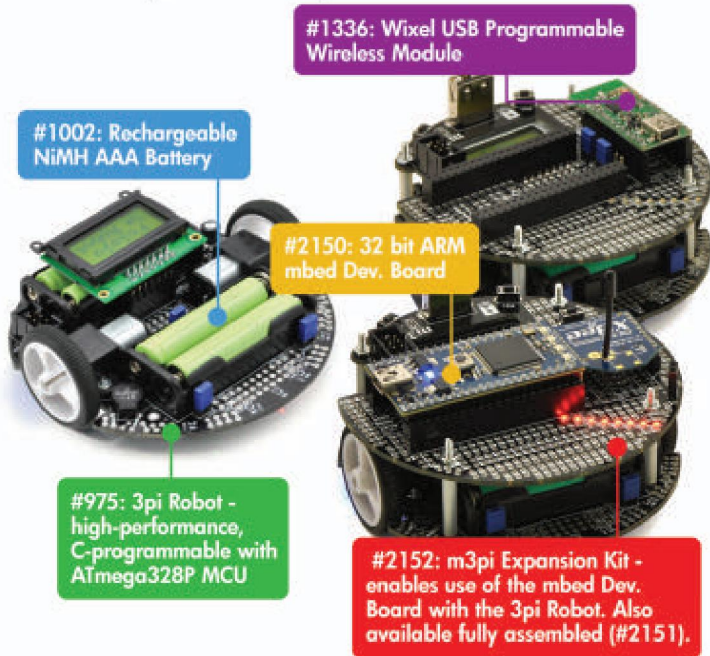
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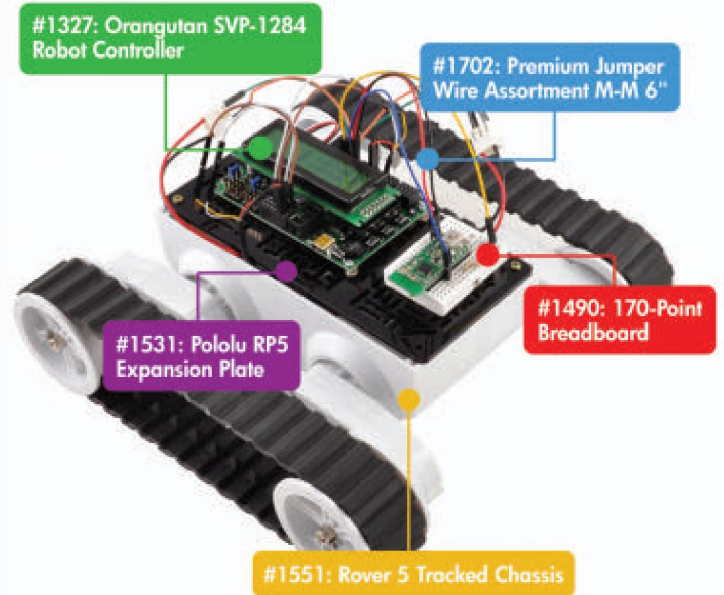
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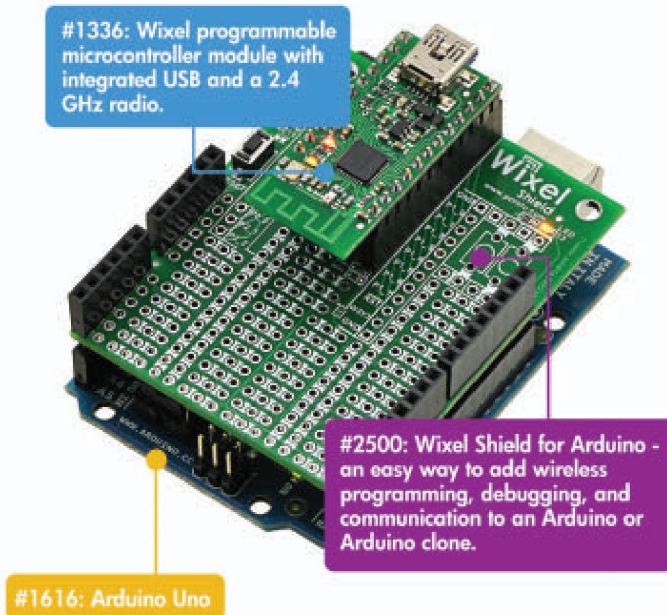
## Robots and Robot Kits: Pololu 3pi and m3pi



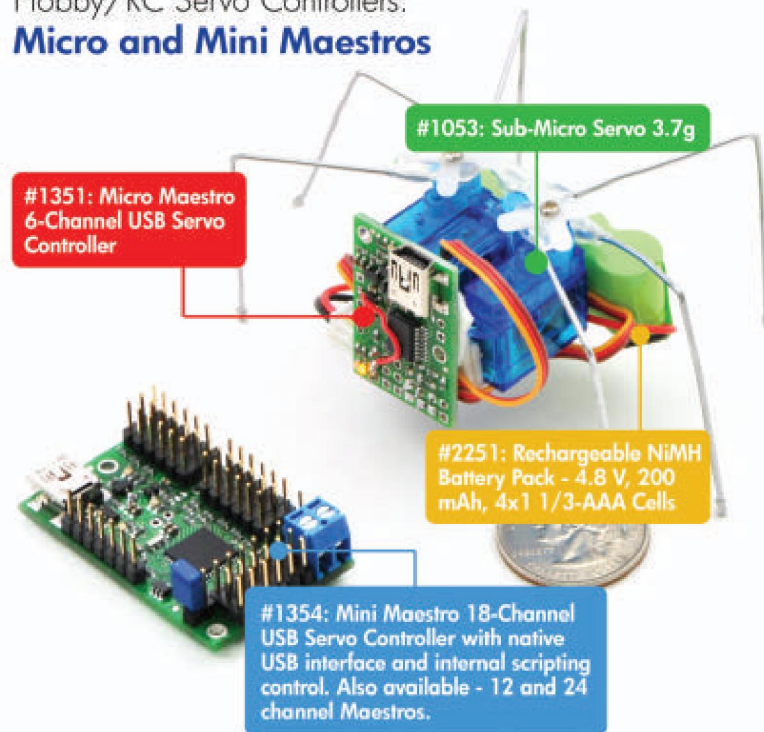
## DIY Projects: Simple Tracked Robot



## Programmable Controllers: Wixel and Wixel Shield



## Hobby/RC Servo Controllers: Micro and Mini Maestros



Finding the right parts for your robot can be difficult, but you also don't want to spend all your time reinventing the wheel (or motor controller). That's where we come in: Pololu has the unique products - from actuators to wireless modules - that can help you take your robot from idea to reality.